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MR. E. J. B. GREENWOOD, M.Sc., M.I.E.E., M.I.E. (IND.)

PRESIDENT 1938-39

THE JOURNAL
OF
The Institution of Engineers (India)
INCORPORATING THE TRANSACTIONS OF THE LOCAL CENTRES

Edited and Published for the Institution by the Secretary, Rai C. C. Seal Bahadur. 135

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CONTENTS

CORRIGENDUM.

The paragraph at the bottom of page 10 of the Journal Vol. XVIII be substituted by the following paragraph :—

"A London office has been opened and a new Standing Committee called 'The London Committee of the Institution' formed to act as a liaison body between the Council and the various Engineering and Technical Institutions and the other authorities with whom the Institution is likely to have relations, and to further the interests of the Institution in England generally."

The Institution of Engineers (India)

LIST OF RECIPIENTS OF PRIZES FOR PAPERS.

Name.	Subject.	Particulars of Prize.	Date of award.
Mr. H. F. Davy ..	Portland Cement in India ..	His Excellency the Viceroy's Prize.	July 1922.
,, D. G. Harris ..	Irrigation in India ..	ditto ..	April 1923.
,, A. Lennox Stanton	Railway Electrification with special reference to Indian Conditions.	Institution of Electrical Engineers' premium.	May 1923.
,, D. R. MacIntosh	An Examination of the New Indian Boiler Regulations 1924.	His Excellency the Viceroy's Prize.	Feby. 1924.
Messrs. F. C. Temple & V. N. Sarangdhar.	Jamshedpur Sewage Disposal Works with special reference to the activated Sludge Plant.	ditto ..	Aug. 1925.
Mr. J. McGlashan ..	New 80 ft. Lock Entrance into the Kidderpore Docks.	ditto ..	Jan. 1927.
,, A. Lennox Stanton	Railless or Trackless Trolley System.	ditto ..	Sept. 1928.
,, C. I. Stabler ..	The Reconstruction of the 2′ 6″ Gauge Bridge across the Nerbudda River.	ditto ..	Nov. 1929.
,, F. C. Temple ..	Notes on the Design of Sewage Disposal Works.	ditto ..	Nov. 1930.
,, A. N. Mitra ..	Rivers in Western Bengal and Orissa.	ditto ..	July 1931.
,, C. I. Stabler ..	Bridge Construction with particular reference to Foundations in Indian Conditions.	Railway Board's .. 1st Prize.	April 1931.
,, F. C. Temple ..	Septic Tank Installations for Workshops and small residential areas.	Railway Board's .. 2nd Prize.	April 1931.
,, C. I. Stabler ..	Bridge Construction with particular reference to Foundations in Indian Conditions.	His Excellency the Viceroy's Prize.	Nov. 1932.
,, N. V. Dorofeef ..	Tunnelling in connection with the Uhl River Hydro-Electric Scheme.	ditto ..	Feby. 1934.
,, S. Kamesam ..	A new principle in Wood Preservative Impregnation Technique, and its application—with special reference to Chir (Pinus Longifolia) for Railway Sleepers.	ditto ..	Feby. 1934.
,, A. R. Beattie ..	The B. T. U. in an Indian Paper Mill.	ditto ..	Nov. 1934.
,, Salil Chandra Ghose	A new Development in Portable Radio Field strength measuring apparatus.	Institution of Electrical Engineers' Premium.	June 1935.
,, A. R. Beatie ..	Influence of combined Power and Process Plant in an Indian Paper Mill.	His Excellency the Viceroy's Prize.	Dec. 1935.
,, G. Bransby Williams	The Design of Masonry Gravity Dams.	ditto ..	Oct. 1936.
,, M. L. Garga ..	Design and Construction of Tinai Nadi Aqueduct (Sarda Canal).	ditto ..	Oct. 1937.
,, A. Vasudevan	Modern Tendencies in Design & Construction of Track.	ditto ..	• July 1939.

The Institution of Engineers (India).

Post Box No. 669, Calcutta.

Message from Pundit Madan Mohan Malavya, Vice-Chancellor, Benares Hindu University (read out by Raja Jwala Prasad, Pro Vice-Chancellor).

"" On behalf of the Benares Hindu University I offer members of the Institution of Engineers a most cordial welcome. The University feels honoured that you have selected this place for holding your Annual Conference this year. I hope this will be the beginning of a close co-operation between members of the Institution of Engineers and of the University in the future work of the University, particularly in the domain of Engineering. I wish your Conference every success."

Minutes of proceedings of the Nineteenth Annual General Meeting held at the Arts College Hall of the Benares Hindu University, Benares, on Friday, the 13th January 1939 at 10 A.M.

PRESENT

Mr. Fakirjee E. Bharucha (in the Chair).
Mr. E. J. B. Greenwood (later in the Chair).
Raja Jwala Prasad.
Rai Bahadur B. P. Varma.
Mr. G. Bransby Williams.
Mr. S. K. Chakravarti.
Mr. S. B. Joshi.
Mr. B. R. Kagal.
Khan Bahadur A. G. Khan.
Mr. T. R. S. Kynnersley.
Mr. Mohsin Ali.
Mr. Siri Ram.
Mr. R. K. Sarkar.
Mr. H. G. Trivedi.

With 38 Corporate Members, 2 Associates and 1 Student.
Rai C. C. Seal Bahadur (Secretary).

PROCEEDINGS.

1. Mr. Fakirjee E. Bharucha referred to the serious Railway accident which occurred on the 12th January 1939 and which prevented several members of this Institution from attending the Annual Session; he expressed deep sympathy and sincere condolence for those passengers who suffered from the accident, and at his request all the members present at the meeting joined him by standing in silence to offer a short prayer for their peace.

2. Rai Bahadur B. P. Varma proposed that the Minutes of the Eighteenth Annual General Meeting, copies of which had been previously circulated, be taken as read and confirmed.

Mr. B. R. Kagal seconded.

The proposal was put to vote and was carried unanimously.

3. Rai Bahadur B. P. Varma proposed that the Annual Report for the year ending 31st August 1938 be adopted and the accounts passed.

Mr. R. K. Sarkar referred to the item for depreciation of building in the accounts and said that the rate at which the depreciation has been calculated appeared to be $2\frac{1}{2}\%$. In his opinion, for a first class building 40 years' life was too short.

Diwan Bahadur V. G. Shete in seconding suggested the following additions and alterations :—

(1) Mr. D. H. Remfry's name should appear in the list of members of Council *re-elected*;

(2) the sentence, *viz.* "But definite boundaries were not formally assigned to it" at the bottom of page 6 be deleted; and

(3) the sentence, "but his report has not yet been received" appearing in para 10 be deleted and the following sentence inserted in its place, *viz.* "Mr: Modak's report has since been received and is under consideration of the Council."

He also suggested that abstracts of all the papers accepted as Institution papers together with abstracts of the discussions should be printed in the Journal, that the accounts of the Local Centres be printed in the Annual Report, and that monthly Journals should be introduced.

Mr. S. B. Joshi disagreed with Diwan Bahadur Shete so far as Mr. Modak's report was concerned and suggested that the report be read at the Annual General Meeting. Further he pointed out the discrepancy between the membership tables and the abstract in para 1, and suggested that in future these tables should be prepared in consultation with Local Centres.

Raja Jwala Prasad agreed with Mr. R. K. Sarkar and said that the depreciation on the Institution Building should be correctly calculated and printed in the Annual Report as accurately as possible; he suggested that $\frac{1}{2}\%$ would be a fair rate.

The Chairman said that in his opinion it would be better to provide the larger sum of money under depreciation; on other points he supported Diwan Bahadur Shete and Mr. S. B. Joshi.

(*a*) *RESOLVED* that the accounts be passed and the Annual Report be adopted subject to the following additions and alterations :—

(1) Mr. D. H. Remfry's name be shown in the list of members of Council re-elected.

(2) The following sentence be omitted from para 3 :— "But definite boundaries were not formally assigned to it."

(3) The following sentence be omitted from para 10 :— "but his report has not yet been received" and the following sentences be inserted in its place :—

"A copy of his report is appended below :—

As desired by the Council, I had an interview first with Mr. Bransby Williams, the Secretary of the London Branch, in connection with the recognition of the A.M.I.E. examination by the Institution of Civil Engineers. He informed me that

the matter was taken up by the London Branch with the Institution of Civil Engineers and from the discussion or talk he and Col. Temple had, it appeared that there were no chances of our Institution Examination being recognised as equivalent to the Associate Membership Examination of the Institution of Civil Engineers. He also thought that any negotiations in this connection would be of no use. I, however, requested him to give me an opportunity of discussing this matter with the Secretary of the Institution of Civil Engineers and also with the Secretaries of the Institutions of Mechanical and Electrical Engineers, so that I might place before them our point of view. He was good enough to arrange for meetings with the Secretaries of the three above-named Institutions. I accordingly interviewed the Secretaries of the three Institutions and have to report as under :—

The Institution of Civil Engineers :

The interview was given by the Foreign Relations Officer of the Institution. I had a long discussion with him in connection with the examination of the Institution and other things. He first informed me that the matter was not taken up by the London Branch of our Institution with them officially, but whatever was reported to me by the Secretary of the London Branch was the result of the informal discussion that the Branch had with certain members of the Institution. I told him that we were very anxious to see that the Associate Membership examination of the Institution of Engineers (India) was placed on the same level as that of the Associate Membership examination of the Institution of Civil Engineers, and inquired of him that, if the Institution of Engineers (India) were to send them a copy of the syllabus and copies of the question papers for the last five years along with a list of Examiners to them, whether they would be good enough to go through them and form an opinion as to the quality and standard of the examination held in India. I also assured him that, if they thought that the standard laid down was in any way inferior to that of the Institution of Civil Engineers, the Institution of Engineers

(India) would look into this matter and try to raise the standard, if it were possible to do so. He further informed me that their Institution had some sort of control over the examinations of the University, the degress of which are considered equivalent to the Associate Membership Examination in parts A & B. I pointed out to him that such a course would not be possible in the case of our Institution but suggested that the Indian Institution might consider the question of reserving a certain number of the examiners to the members of the English Institution if it was deemed necessary for recognition. At the end, he informed me that the Institution of Civil Engineers would be too glad to give this matter their very careful consideration and suggested that the whole case be submitted for their consideration officially after my return to India.

The Institutions of Mechanical and Electrical Engineers :

Here also the interviews were very satisfactory and the Secretaries promised to look into the matter if we were to draft a suitable representation to the Institutions forwarding them copies of the syllabus and question papers, together with the names of examiners, etc. for their perusal.

I should therefore request the Council to prepare a proper representation for submission to the three Institutions. I would suggest that all the correspondence in this connection should be carried out directly by our Institution and not through the London Branch, who, however, should be informed of the action taken by the Council in the matter."

(*b*) *RESOLVED* further that the four suggestions, *viz.* (1) that abstracts of all the papers accepted as Institution papers together with abstracts of the discussions thereon should be published in the Journal, (2) that the accounts of Local Centres be printed in the Annual Report, (3) that the depreciation on the Institution building should be calculated at $\frac{1}{2}\%$, and (4) that monthly journals should be issued, be accepted and referred to the Council for consideration.

The Secretary was instructed to prepare the statistics of membership in consultation with the Local Centres.

4. The Chairman announced that under Bye-law 18 the following members had been elected by the Local Centres to fill the vacancies on the Council :—

Mr. H. P. Bhaumik, O.B.E.	..	Bengal Centre.
,, John Chambers, O.B.E.	..	,, ,,
,, S. N. Ghose	..	,, ,,
,, S. C. Majumdar	..	,, ,,
Dr. Geo. W. Burley	..	Bombay Centre.
Dr. K. C. Chakko	..	South India Centre.
Dewan Bahadur C. V. Krishnaswamy Chetty	..	,, ,, ,,
Mr. V. H. Sadarangani	..	,, ,, ,,
Mr. Mohsin Ali	..	United Provinces Centre.
,, R. K. Sarkar	..	,, ,, ,,

5. The Chairman announced that under clause 6 (b) of the Charter the following members, who had been elected Chairmen of the respective Local Centres, would become *ex-officio* Vice-Presidents of the Council :—

Mr. H. P. Bhaumik, O.B.E.	..	Bengal Centre.
,, T. R. S. Kynnersley	..	Bombay ,,
,, N. Sarabhoja	..	Mysore ,,
,, A. C. Flower	..	South India Centre.
,, Mohsin Ali	..	United Provinces Centre.
Dewan Bahadur Amar Nath Nanda ..	..	N. W. I. Centre.

And that the following past Presidents would become *ex-officio* Members of Council :—

Rai Bahadur B. P. Varma.

Col. F. C. Temple, C.I.E.

Rai Bahadur Chhuttan Lal.

Mr. Fakirjee E. Bharucha.

6. Mr. Bharucha delivered the following Address :—

"Gentlemen,

The annual report has already been circulated to the members and I have nothing to add to it. As usual the report provides a very dry and dull reading, and does not give us any idea as regards the advancement of engineering education and engineering fraternity during the past year in this country.

I know our Institution is still in its infancy or should I say in its teens? But we have got examples of other similar chartered engineering institutions in England, some established about a century ago, and it is time that we should make long strides and emulate them by deriving much benefit from their past experiences and elaborate efforts.

Our country being very wide and of long distance the President of this Institution, when he resides at a distance of more than a thousand miles from its headquarters (as has been in my case), cannot do much, nor can keep himself in personal touch with the Council at headquarters. I found that the Secretary consulted more often the Vice-President than the President on several important matters. I wonder if it could not be possibly and conveniently arranged to shift the office of the Secretary temporarily to the place where the President resides and the work of the Institution carried out with the help of the Members of the Council of the local centre for the year.

However, I am of opinion that the time has come when we should have a full time qualified Engineer-Secretary. I may here tell you, gentlemen, that I have nothing to say personally against Rai Bahadur Seal. He has performed his duties up till now according to his ability and capability and we are thankful to him for what he has done during the past so many years in spite of the fact that he is not an engineer by education or profession.

But now our membership is on an increase and we have built up a good reserve fund and can afford to engage a qualified Engnieer-Secretary full time. It is also necessary that we publish a monthly official journal edited by our Secretary in which accounts of our main and important activities, papers read and discussed at all our centres may be published together with talks, thoughts and suggestions of our members on current engineering problems.

Another matter, which I found called for improvement, was the care and scrutiny of the question papers of our Institution examinations. Certain incidents occurred which made it essential that the printing of these papers and their custody be improved. In this connection I am much indebted to Mr. M. I. D. Mufti and to the members of the special sub-committee, particularly Mr. S. B. Joshi.

I called several meetings of the local members of Council in Bombay and suggested reforms to be introduced in the procedure of the examination.

On page 8 of our annual report it has been stated that the report of Mr. Modak, City Engineer, Bombay Municipality has not been received, it being the report for the year ending August 1938. Mr. Modak was deputed by our Council to interview the Secretaries of the Institutions of Civil, Mechanical and Electrical Engineers, London, with a view to have our examinations for Associate Membership being recognized by them. Mr. Modak has now submitted his report from which it appears that he succeeded in creating good impression on the minds of the Secretaries of those Chartered Institutions who have promised to place our case before their respective Councils for favourable consideration when submitted by us. We are all very thankful to Mr. Modak for having taken so much trouble on behalf of our Institution and bringing about such a healthy atmosphere for the consideration of our grievances by the English Institutions which also hold Royal Charters similar to ours, and therefore are of equal rank with us.

The two most important events of the year were the approval of our Bye-laws by the Privy Council and the creation of a new local centre at Hyderabad. 120 new members joined the Institution during the year. The fact that 100 applications out of 315 were rejected shows that the Council were very careful to see that standard for admission was not lowered. This year 6 papers were accepted against 2 in the previous year. This shows that the members are taking more interest in the matter. However, we want more papers on subjects pertaining to mechanical engineering and industrial technology as well, such as sugar, leather, cotton, jute, etc., etc. We received a paper on "Indian Paper Industry" which I liked very much. We are looking forward to rapid industrial regeneration

of our country and we should welcome such papers giving valuable information gleaned from personal experience obtained in the climatic and economic condition of our country.

Before I hand over the chair of Presidentship to the newly elected President, Mr. E. J. B. Greenwood, I must thank the members of our Council and the Secretary for the help they have rendered me.

I have now great pleasure in introducing our new President, Mr. E. J. B. Greenwood, M.Sc., M.I.E.E. He was the Electrical Inspector and Engineer to Government of Madras and at present he is holding the post of Deputy Chief Engineer in the Electricity Department of Madras, P.W.D. He was elected a member of our Institution in 1920 and has been a Member of Council since 1923. He was the Chairman of South India Centre for the year 1931-32. Mr. Greenwood was born in 1886 at Brighton and was educated at Plymouth College. He received his engineering training in Leeds University and served for over 7 years in Colchester, Wakefield and Manchester in various works."

Mr. Greenwood then took the Chair and delivered his Presidential Address.

7. The Chairman said that under Bye-law 57 it would be necessary to appoint Auditors to hold office until the next Annual General Meeting, and to fix their remuneration.

Mr. J. Ganguly proposed and Mr. A. N. Bose seconded that Messrs. Price, Waterhouse, Peat & Co., be re-appointed Auditors on the same remuneration, *viz.* Rs. 350/-.

The proposal was put to vote and was carried unanimously.

8. Mr. B. R. Kagal moved the following resolution :—

This Meeting is of the opinion that the Engineering Curricula of the different Universities require re-orientation so as to make them suit the modern conditions. The advance that engineering science has made during the last twenty years has revolutionised Engineering practice. This Meeting is, therefore, of the opinion that it is necessary to appoint an Education Sub-Committee of the Council on the lines of the other Sub-Committees, and this Committee should submit a Memorandum to the Council before the end of the year incorporating

their findings as to what changes they consider necessary to be introduced in Engineering education. It is suggested that in preparing this Memorandum the members representing the local Centres, should consult the various Engineering institutions within the limits of their Centre.

He prefaced this resolution with the following forceful speech :—

Mr. President & Brother Engineers,

The resolution that is standing in my name, and which I am moving with as much earnest as I am capable of translating into words, could have been moved by me before your Council. Under the constitution they are competent to deal with it. Even so, I have ventured to encroach upon your valuable time because the subject matter is so vital to every one of the present and future Engineers. I want your sanction, your support and your co-operation. When I say you—I mean both the General Body as well as every individual member. I have no doubt I shall have your whole-hearted support now. But even for making an honest and humble beginning such as I now propose for useful and necessary work, if I find opposition from self-complacent and self-satisfied elements, I shall continue to agitate until every one of us is convinced of the need for action and immediate action for that matter.

I have not had the time to visit all the local Centres to find how they would react to such a proposal. However last X'mas I visited Bombay and met the Chairman of the Centre for the ensuing year, Mr. T. R. S. Kynnersley. His enthusiasm for active work is well-known and I have no doubt Bombay will be one of the foremost Centres for taking up work on the lines outlined in the resolution in right earnest. I am equally sure that other Centres will also give similar response without any hesitation. All that I beg is your sanction and enthusiastic support.

Those who are interested in the growth and usefulness of this Institution must have at one time or another seriously considered the various activities of the Institution and must have given thought to the lines along which improvements could be made. I have no doubt you all will agree that with the grant of the Royal Charter, the Institution has assumed greater

importance, and with that, greater responsibility. I shall, therefore, not waste your time beyond mentioning it in passing.

I am inclined to divide the work before us into two broad categories—the passive and the active. The passive work is in the nature of enrolling members, exercising control over their conduct and generally helping the professions to conduct the work satisfactorily. Publishing information and giving publicity to the activities of the Institution and its different Centres and examining for purposes of acceptance papers and theses which are considered of a sufficiently high standard in the matter of originality and research—all this work though very onerous is only of a passive kind.

Active work, in my opinion, would include, for instance, a survey of the conditions under which various branches of Engineering in India are working and examining ways and means by which conditions could be improved where necessary. Again we might actively contribute towards the betterment of Engineers by studying the reasons and methods of combating unemployment which, you all know, is growing amongst our younger generation of Engineers. I say that it is possible for this Institution to do useful work in a very active manner along the lines suggested above or along any other lines that we can think of, but the proposition that I am placing before you is not as ambitious as all that. My proposal is a very modest one and in my opinion it is the minimum that we can do at this stage of our Institution's development.

The acute condition of unemployment amongst the lower and upper middle class of people in India led to various kinds of searching enquiries into the present system of education. You all know that, although educationists are not all agreed as to how the present system could be improved, there are, however, no two opinions with regard to the inadequacy and the unsatisfactory nature of the existing system of education, primary, secondary and collegiate. All are agreed that the present system needs revision and the Central and the Local Governments are making frantic efforts to devise suitable changed curricula to suit the present conditions. The Wardha Scheme, the Government of India's various circulars on educational policy and recruitment are all results of these efforts at reform.

We, Engineers, are always credited with forethought and planning for the future. My present proposal is nothing but an attempt to bring and keep engineering education on a satisfactory basis, so that we may not have to face acute and distressing conditions amongst the younger generation before we make a beginning.

The practice of engineering, based on scientific advances during the last 50 years, has been almost revolutionised in many branches. Are we satisfied that the Engineering curricula of the various Universities have kept pace with recent advances? My answer to this question is a definite NO.

India is industrialising at a very great pace and recent political changes have, if anything, accelerated our pace of industrialization. The All India Committee, that is at present considering the question of industrial planning, is a very vivid example of active promotion and acceleration of this process.

When a predominantly agricultural country with a population of nearly 400 millions, rapidly industrializes, new problems affecting town planning, housing of the industrial workers, traffic control, etc., must necessarily arise. Take only one instance. A large number of our young graduates are absorbed as Local Board & District Board Engineers. Municipal Corporations and Town Municipalities also provide for a number of our fresh men. Even a cursory glance over the University curricula would show that the problems which vitally affect the employers of our young Engineers in the category mentioned above are hardly dealt with at any of the Universities. It is no wonder, therefore, that in a large number of cases a non-Engineer is preferred while the post should have rightly gone to a suitably trained Engineer. A city Engineer of a Municipal Corporation like Bombay can have little use for a University Engineering graduate, who has not been trained in the elementary principles of land acquisition and valuation, town planning and traffic problems peculiar to the 20th century. The London University, for instance, gives equal importance to the subject of Estate Management and Town Planning with civil, electrical and mechanical engineering. I know of several large estates which are crying out for suitably trained Engineer-Managers, while our freshers continue in vain to worry already embarrassed contractors for posts on untrained *mistri's* pay.

It is a truism to say that our curricula were originally intended for an agricultural country, but with the changed industrial conditions and under the new dispensation of things, a re-orientation to suit the present requirements has become necessary.

I suggest that on the Committee that I have proposed we should have one or more members from each Centre. I say, one or more, because the members at each Centre should be fairly representative of the Engineering profession and, therefore, a large number is not likely to be a handicap in work. The members at each Centre could then get in touch with the Engineering Faculties of their respective areas and should thus serve as a liason Committee between the Institution and the area concerned. These Committees should meet as often as necessary. In any case the full Committee should meet *before* the Annual General Meeting and submit its report to the Council Meeting held along with the Annual General Meeting. If you agree, you may leave the details of the procedure to the Council to decide.

I have no doubt that as a result of the discussion that will now follow, more valuable suggestions would come up and your Council would be able to come to a decision in the matter after hearing your views.

I again submit that my proposal is a very modest one suggesting a beginning for active work for the Institution and I have no doubt you will unanimously support me and thus keep the future generation of Engineers under a deep debt of gratitude.

Principal Shiv Narain seconded the resolution.

The Secretary placed on the table letter No. C/227/39 dated 9-1-39 from the Honorary Secretary, Bombay Centre, on the subject.

Mr. T. R. S. Kynnersley and Raja Jwala Prasad supported the proposal.

RESOLVED that the Council be informed that the general meeting supports the resolution, and requested to take necessary steps to give effect to it.

9. Mr. B. R. Kagal moved the following resolution :—

This meeting is of the opinion that an Information Bureau should be established at the Headquarters, as early as possible,

and the following Sub-Committee be appointed to work out the details and submit them for the approval of the Council within six months.

After some discussion, in which Khan Bahadur A. G. Khan, Mr. R. P. Mathur, Mr. G. Bransby Williams, the Chairman and the mover took part, Rai Bahadur B. P. Varma suggested the following resolution :—

This meeting is of the opinion that Mr. Kagal's proposal for the establishment of an Information Bureau at the Headquarters of the Institution be referred to the Council for examination and report at its next Annual General Meeting.

Mr. S. B. Joshi seconded.

The resolution was put to vote and was carried unanimously. The meeting was adjourned till after the Papers meeting which was to be held at 2-30 P.M. the same day.

Minutes of the adjourned Nineteenth Annual General Meeting of the Institution of Engineers (India) held at the Arts College Hall of the Benares Hindu University, Benares, on Friday, the 13th January, 1939 at 4-35 P.M.

PRESENT

Mr. E. J. B. Greenwood (in the Chair).
Raja Jwala Prasad.
Rai Bahadur B. P. Varma.
Mr. Fakirjee E. Bharucha.
,, G. Bransby Williams.
,, S. K. Chakravarti.
,, S. B. Joshi.
,, B. R. Kagal.
Khan Bahadur A. G. Khan.
Mr. T. R. S. Kynnersley.
,, Mohsin Ali.
,, Siri Ram.
,, R. K. Sarkar.
,, H. G. Trivedi.

With 32 Corporate Members, 2 Associates and 2 Students.
Rai C. C. Seal Bahadur (Secretary).

PROCEEDINGS.

10. Mr. J. Ganguly moved the following resolution :—

That the draft Act for the Registration of Engineers (prepared by the Bengal Centre, *vide* enclosure), which has been before the Council of the Institution for some time, be now discussed with a view to ascertaining the opinions of the general body of members.

Mr. S. K. Chakravarti seconded.

Mr. G. Bransby Williams moved the following amendment :—

That a recommendation be made to the Council that a special committee be formed to go through the matter and report at the next Annual General Meeting.

Mr. Fakirjee E. Bharucha supported.

Raja Jwala Prasad moved the following amendment :—

That the General Meeting accepts the principle of the Bill and refers it to the Council for consideration and report.

Mr. G. Bransby Williams supported and withdrew his amendment.

Mr. J. Ganguly having agreed to the amendment moved by Raja Jwala Prasad, the matter was put to vote and was carried by a majority.

11. Rao Saheb N. S. Joshi moved the following resolution :—

This meeting resolves that the Institution should publish a monthly Journal, which should include (*i*) Original Papers and communications on Engineering questions, (*ii*) Résumé of the activities of the Institution including those of its Local Centres, (*iii*) Summary and Report of Research Work in Engineering and other Engineering undertakings in India and outside, and (*iv*) All matters that are likely to be of interest to the profession of Engineers.

The Council should make the necessary arrangements for the publication of the Journal from April 1939.

Mr. Fakirjee E. Bharucha seconded.

After some discussion in which Mr. T. R. S. Kynnersley, Mr. J. Ganguly and Mr. S. B. Joshi took part, it was resolved that the Council be informed that the General Meeting desires that a monthly journal should be published on the lines suggested by the mover and that a copy of this resolution be submitted to the Council for necessary action as early as possible.

12. Mr. S. B. Joshi moved the following resolution :—

This meeting records its emphatic protest against the policy of employers of Engineers, including the Government and other Local Authorities, of giving preference to degrees and diplomas of foreign universities and institutions in filling posts in their service. It is the considered opinion of this meeting that such discrimination is unnecessary in view of the present high standard of Indian degrees and diplomas in Engineering.

Rao Saheb N. S. Joshi seconded.

The resolution was put to vote and was carried unanimously.

13. Mr. S. B. Joshi moved the following resolution :—

This meeting notes with regret that the Government of India, Local Governments and the Municipalities and other Public Bodies do not consult this Institution on questions affecting Engineering. This meeting directs their attention to object (g) of our Charter whereby we offer them facilities for conferring on matters affecting Engineering. This meeting impresses upon them the advisability of consulting representative Institution like the Institution of Engineers (India) instead of relying on views of officials and other individuals.

Mr. B. R. Kagal seconded.

After some discussion in which Raja Jwala Prasad, Mr. S. K. Chakravarti, and Mr. R. P. Mathur took part, Raja Jwala Prasad moved the following amendment, *viz.* that the words "instead of relying on the views of" in the last sentence of the resolution, be replaced by "in addition to the".

The resolution as amended above, was put to vote and was carried unanimously.

14. Mr. S. B. Joshi moved the following resolution :—

This meeting notes with pleasure the passages from the report of the Council 1937-38 of the Institution of Civil Engineers, London, appended to this resolution and records its appreciation of the general policy laid down by the said Institution with regard to its relations with sister Institutions in the British Empire.

This meeting appeals to the sister Institutions in Great Britain to extend their co-operation to the Institution of Engineers (India) in all matters affecting Engineering and to reduce the duplication of examinations by recognizing Corporate Membership of this Institution and its examinations, and by further recognizing the Engineering degrees of Indian Universities.

The Institution of Engineers (India) trusts that such mutual co-operation between chartered Institutions having jurisdiction over different parts of the Commonwealth will conduce to the advancement of Engineering Science in the British Empire.

The Institution requests and authorizes Mr. G. E. Bennett and Mr. N. V. Modak to conduct further negotiations with the sister Institutions in England on behalf of this Institution with a view to bringing about mutual co-operation as aforesaid.

The Institution is thankful to Mr. N. V. Modak for the work he has already done in this behalf during his recent visit to England.

APPENDIX

(Referred to in line 2 of the resolution)

[Passages :—The Council have continued to seek close co-operation with other Engineering Societies in the firm conviction that the Institution is in a position to assist collaboration between Specialist Societies and to promote co-ordination among all professional Engineers.

Proposals for securing co-operation between members of British Engineering Institutions, resident overseas are at present receiving the consideration of the constituent Institutions of the Engineering Joint Council, and the Council of the Institution have agreed to explore the proposals with a view to ascertaining whether they would be generally acceptable.

With a view to reducing the duplication of examinations, the Council, while bearing in mind the necessity for maintaining the standard of qualifications necessary for election into the Institution, have extended the list of qualifications exempting in whole or in part from the Institution examinations to include Corporate Members of the following Institutions who have qualified by examination under the current regulations of the respective bodies:

The Institution of Mechanical Engineers
,, ,, ,, Electrical ,,
,, ,, ,, Structural ,,
,, ,, ,, Municipal & County Engineers.

The Council have also given close consideration to the question of recognition of certain degrees of Indian Universities for the purpose of exemption from Sections A & B of the Associate Membership examination. An application was received from the Bombay University, as a result of which the honours degree in Civil Engineering of that University, if obtained under certain conditions, is to be so accepted.]

After some discussion it was decided that a copy of Mr. Joshi's resolution be submitted to the Council with the request to form a Sub-Committee with Mr. G. E. Bennett, Mr. N. V. Modak and such other members as may be co-opted by the Council, to conduct further negotiations as suggested by Mr. Joshi.

15. Mr. S. B. Joshi moved the following resolution :—

That under Bye-law 50, the number of members, that will constitute the Council, be fixed 38 in addition to the *ex-officio* members and irrespective of Members or Associate Members.

Principal Shiv Narain supported.

The resolution was put to vote and was carried unanimously.

16. In the absence of Mr. P. P. Adalja, Mr. S. B. Joshi moved the following resolution :—

(1) This Institution resolves :—

> That Government of India, Local Governments and Local Authorities be approached to send us copies of all scientific publications and project reports as and when they are available for reference.

(2) That this meeting directs the Council to frame conduct rules for corporate members acting in different capacities and professional practitioners in India, and place the same for approval at the next year's general meeting.

(3) This meeting directs the Council to make inquiries into the question whether :—

(i) Adulterated cements by mixing inferior brands or stone dust, (ii) old stock affected by moisture, (iii) reground stuff of caked cement are being sold by cement stockists in India. If so, it is highly detrimental to the strength of structures, dangerous to the cause of public, and undesirable; and therefore, necessary steps be taken by the Institution to prevent such malpractices.

Principal Shiv Narain seconded.

RESOLVED that the principle outlined in the resolution be accepted.

With a hearty vote of thanks to the Chair moved by Mr. Fakirjee E. Bharucha and seconded by Mr. J. Ganguly, the meeting terminated.

ANNUAL REPORT OF THE COUNCIL

For the year ending 31st August, 1938.

1. MEMBERSHIP.—The changes in membership at the various Local Centres are shown in the following tables :—

BENGAL CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-37 ..	3	..	113	188	3	85	13	11	416
Additions :—									
Elected ..	..	..	2	12	..	28	..	..	42
Transferred ..	..	..	1	6	..	2	..	..	9
Total Additions ..	..	..	3	18	..	30	..	..	51
Deductions :—									
Transferred ..	..	..	2	4	..	5	..	..	11
Deceased ..	..	..	1	..	..	..	..	..	1
Resigned ..	..	..	3	1	..	2	..	..	6
Struck off ..	..	..	1	5	..	5	2	..	13
Total Deductions ..	..	..	7	10	..	12	2	..	31
Membership on 31-8-38..	3	..	109	196	3	103	11	11	436

BOMBAY CENTRE.

	Life Members.	Members.	Life Associate Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31st August 1937 ..	3	66	.	233	1	37	1	1	342
Additions upto 31st August 1938.—									
Elected ..	..	7	1	24	..	5	..	..	37
Transferred ..	9	4	2	18	.	3	..	..	36
Total Additions ..	9	11	3	42	..	8	..	..	73
Deductions upto 31st August 1938 :—									
Transferred ..	1	12	..	20	..	1	..	..	34
Deceased ..	..	..	..	2	..	..	..	..	2
Resigned ..	..	2	..	2	..	1	..	..	5
Struck off ..	..	1	..	.	..	11	1	..	13
Total Deductions ..	1	15	..	24	..	13	1	..	54
Membership on 31st August 1938 ..	11	62	3	251	1	32	..	1	361

SOUTH INDIA CENTRE.

	Life Members.	Members.	Life Associate Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31st August 1937 ..	..	24	..	82	..	48	1	..	155
Additions :—									
Elected ..	..	1	..	7	..	11	..	..	19
Transferred ..	..	..	..	5	..	..	..	..	5
Total Additions ..	..	1	..	12	..	11	..	..	24
Deductions :—									
Transferred ..	..	2	..	3	..	..	..	..	5
Deceased ..	..	..	..	..	..	1	..	..	1
Resigned ..	..	1	..	2	..	4	..	..	7
Struck off ..	..	..	..	2	..	4	..	..	6
Total Deductions ..	..	3	..	7	..	9	..	..	19
Membership on 31st August 1938 ..	..	22	..	87	..	50	1	..	160

NORTH WEST INDIA CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31-8-1937 ..	2	..	32	81	..	23	4	..	142
Additions :—									
Elected ..	.	..	2	8	..	2	..	..	12
Transferred ..	..	..	3	6	..	2	..	..	11
Total Additions ..	..	..	5	14	..	4	..	..	23
Deductions :—									
Transferred ..	..	..	1	6	..	3	1	..	11
Deceased ..	..	..	3	1	..	..	..	..	4
Resigned ..	..	..	1	..	..	..	..	..	1
Struck off ..	..	..	..	1	..	3	1	..	5
Total Deductions ..	..	..	5	8	..	6	2	..	21
Membership on 31-8-1938 ..	2	..	32	87	..	21	2	..	144

U. P. CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31st Aug. 1937 ..	1	..	29	76	..	16	8	..	130
Additions :—									
Elected ..	..	..	..	3	..	4	..	..	7
Transferred ..	..	..	3	4	..	..	2	..	9
Total Additions ..	..	..	3	7	..	4	2	..	16
Deductions :—									
Transferred ..	..	..	1	7	..	4	1	..	13
Resigned ..	..	..	..	..	..	2	..	..	2
Struck off ..	..	..	1	..	..	2	..	..	3
Total Deductions ..	..	..	2	7	..	8	1	..	18
Membership on 31st August 1938 ..	1		30	76	..	12	9	..	128

MYSORE CENTRE.

	Hon. Members.	Hon. Life Members.	Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTAL.
Membership on 31st August 1937 ..	..	..	30	44	..	6	..	..	80
Additions :—									
Elected ..	..	..	..	3	..	..	..	..	3
Total Additions ..	..	..	..	3	..	..	..	..	3
Deductions :—									
Transferred ..	..	..	3	2	..	..	..	..	5
Struck off ..	..	..	1	..	..	..	..	..	1
Resignation ..	..	..	2	1	..	..	..	..	3
Total Deductions ..	..	..	6	3	..	..	..	..	9
Membership on 31st August 1938 ..	..	..	24	44	..	6	..	..	74

ABSTRACT.

Bengal Centre ..	3	..	109	196	3	103	11	11	436
Bombay Centre ..	2	..	71	254	1	32	..	1	361
South India Centre ..	1	..	21	87	..	50	1	..	160
North West India Centre ..	2	..	32	87	..	21	2	..	144
United Provinces Centre ..	1	..	30	76	..	12	9	..	128
Mysore Centre ..	..	..	24	44	..	6	..	..	74
Outside India ..	2	3	92	18	..	3	1	..	119
Total ..	11	3	379	762	4	227	24	12	1422

120 new members joined. Deducting the number of members resigned, deceased or struck off, there was a net increase of 47 against 34 of the previous year.

The total number of applications received during the year was 315, of which 122 were approved, 20 were approved subject to passing the necessary examination, 100 were rejected, 17 were returned being incomplete and 56 were under consideration at the close of the year.

2. COUNCIL.—Mr. Fakirjee E. Bharucha was the President for the year.

The following members retired from the Council :—

(a) Mr. P. N. Banerjee.
(b) Dr. Geo. W. Burley.
(c) Mr. Fakirjee E. Bharucha.
(d) Dewan Bahadur K. R. Godbole (deceased).
(e) Rao Bahadur G. Nagaratnam Ayyar.
(f) Mr. N. V. Modak.
(g) Mr. D. H. Remfry.

The following members were re-elected :—

(a) Mr. Fakirjee E. Bharucha.
(b) Mr. N. V. Modak.
(c) Mr. D. H. Remfry.

The following members were newly elected :—

(a) Mr. B. S. Chetti.
(b) Dr. A. Jardine.
(c) Mr. S. B. Joshi.
(d) Mr. Framroz D. Mehta.

3. LOCAL CENTRES.—The Bengal Centre held 8 ordinary general meetings, one of which was specially convened for the purpose of drafting an Act for registration of engineers. At the remaining seven meetings papers were discussed and lectures were delivered, the most important of which were the lectures delivered by Professor G. W. O. Howe, D.Sc.,

James Watt Professor of Electrical Engineering at the University of Glasgow and by Professor R. V. Southwell, M.A., F.R.S., Professor of Engineering Science at the University of Oxford, on "Television" and "New Methods of Approximate Calculation in Engineering" respectively. The Annual General Meeting was held on the 7th December 1937 and in that connection a Conversazione was held at which tea was served and several machines, scientific instruments, models and other useful articles of local manufacture were exhibited. Nine visits were paid to Engineering Works.

The Bombay Centre held its 16th Annual Session from 21st to 24th November 1937. The Annual General Meeting was held on the 22nd November and the Annual Dinner on the 23rd November. The Hon'ble Mr. M. Y. Nurie, Bar-at-law, Minister for Public Works, was the chief guest at the Annual Dinner and 87 persons attended. The Centre also held four ordinary general meetings at which papers were discussed and lectures delivered. Five visits were paid to Engineering Works.

The South India Centre held 8 ordinary general meetings for discussion of papers and for lectures. The Annual General Meeting was held on the 4th November 1937. The members visited the Napier Bridge.

The United Provinces Centre held its 17th Annual General Meeting on the 18th November 1937. 3 ordinary general meetings were held at which papers were discussed, and lectures delivered. The members visited six Engineering Works.

The North West India Centre held its Annual General Meeting on the 26th February 1938. 7 ordinary general meetings were held in which various papers were read and lectures were delivered. The members visited two Engineering Works.

The Mysore Centre held its Annual Session from 16th to 20th December 1937. During the Session 12 papers were discussed, four lectures were delivered and visits were paid to six Engineering Works. This Centre held another general meeting for discussion of a paper.

A new Local Centre was formed at Hyderabad (Deccan) at the close of the year.

The Council takes this opportunity of thanking the Hono-raray Secretaries of the Local Centres for the valuable work done by them.

4. NEW BYE-LAWS.—The new Bye-laws were approved by the Privy Council on the 21st October 1937 and came into force from that date.

5. BRITISH STANDARD SPECIFICATIONS.—This Institution continued to act as the Indian Committee of the British Standards Institution of London. 84 Draft British Standard Specifications were sent to this Institution for comments. 66 were disposed of and 18 were under consideration at the close of the year.

Mr. E. J. Hogben continued to act as Adviser to the Council on draft British Standard Specifications up to the middle of March 1938 when he went on leave. Mr. H. F. Davy acted during the remainder of the year. The Council offers its thanks to both of them for the valuable assistance rendered by them.

6. WORLD POWER CONFERENCE AND INTERNATIONAL ELECTROTECHNICAL COMMISSION.—This Institution continued to act as the Indian National Committee of these two bodies.

Mr. E. J. Hogben attended the following meetings as the representative of the Government of India and this Institution :—

(a) Plenary meeting of the International Electro-technical Commission held at Torquay in June 1938.

(b) World Power Conference held in Vienna in August and September 1938.

Mr. A. C. Banerjee continued to act as Adviser to the Council on electro-technical subjects. The Council takes this opportunity of thanking him for the valuable assistance rendered by him.

7. RUBBER TECHNOLOGY CONFERENCE, LONDON.—An invitation was received from the Council of the Institution of the Rubber Industry, London, who organized the conference. Mr. G. Bransby Williams was deputed as a delegate of this Institution and he attended the Conference.

8. ANNUAL INSTITUTION LUNCHEON IN LONDON.—The fifth Annual Luncheon was held at the Criterion Restaurant in London on the 22nd June 1938 under the Chairmanship of Sir Clement Hindley. The total number of members (including guests) who attended the Luncheon, was 44. The toast of the guests was proposed by the Chairman, and the response was made by the Marquess of Zetland.

9. JOURNAL AND BULLETINS.—One Journal and four Bulletins were issued as usual.

10. ANNUAL SESSIONS.—The eighteenth Annual Session was held at Hyderabad (Deccan) from 30th December, 1937 to 3rd January, 1938. In the absence of the President, Khan Bahadur A. G. Khan, one of the Vice-Presidents, presided over the Annual General Meeting. The Presidential Address was delivered by Mr. Fakirjee E. Bharucha, the new President.

Mr. S. B. Joshi moved a resolution drawing the attention of the Council to the fact that the Institution of Engineers (India) has recognized for the purpose of exempting any person from its examination or of electing or attaching any person to any one of the forms of membership of the said Institution or for any other purpose pertaining to any of the objects of the said Institution, the diplomas of many Institutions which have not in return recognized the Institution of Engineers (India) for like purposes, and suggesting that the Council should take such steps as it deems fit and proper to secure such recognition. This resolution was passed and considered by the Council who requested Mr. N. V. Modak, who was to visit England in a few months' time, to get in touch with the authorities of the Institutions of Civil, Mechanical and Electrical Engineers of England through the London branch of this Institution. Mr. Modak had an interview with the officers of the three Institutions. A copy of his report is appended below :—

As desired by the Council, I had an interview first with Mr. Bransby Williams, the Secretary of the London Branch, in connection with the recognition of the A.M.I.E. Examination by the Institution of Civil Engineers. He informed me that the matter was taken up by the London Branch with the Institution of Civil Engineers and from the discussion or talk he and Col. Temple had, it appeared that there were no chances of our Institution Examination being recognised as equivalent to the Associate Membership Examination of the Institution of Civil Engineers. He also thought that any negotiations in this connection would be of no use. I, however, requested him to give me an opportunity of discussing this matter with the Secretary

of the Institution of Civil Engineers and also with the Secretaries of the Institutions of Mechanical and Electrical Engineers, so that I might place before them our point of view. He was good enough to arrange for meetings with the Secretaries of the three above-named Institutions. I accordingly interviewed the Secretaries of the three Institutions and have to report as under :—

The Institution of Civil Engineers :

The interview was given by the Foreign Relations Officer of the Institution. I had a long discussion with him in connection with the examination of the Institution and other things. He first informed me that the matter was not taken up by the London Branch of our Institution with them officially, but whatever was reported to me by the Secretary of the London Branch was the result of the informal discussion that the Branch had with certain members of the Institution. I told him that we were very anxious to see that the Associate Membership Examination of the Institution of Engineers (India) was placed on the same level as that of the Associate Membership Examination of the Institution of Civil Engineers, and inquired of him that, if the Institution of Engineers (India) were to send them a copy of the syllabus and copies of the question papers for the last five years along with a list of Examiners to them, whether they would be good enough to go through them and form an opinion as to the quality and standard of the examination held in India. I also assured him that, if they thought that the standard laid down was in any way inferior to that of the Institution of Civil Engineers, the Institution of Engineers (India) would look into this matter and try to raise the standard, if it were possible to do so. He further informed me that their Institution had some sort of control over the examinations of the University, the degrees of which are considered equivalent to the Associate Membership Examination in parts A & B. I pointed out to him that such a course would not be possible in the case of our Institution but suggested that the Indian Institution might consider the question of reserving a certain number of the examiners to the members of the English Institution if it was deemed necessary for recognition. At the end, he informed me that the Institution of Civil Engineers would be too glad to give this matter their very careful consideration and suggested that the whole case be submitted for their consideration officially after my return to India.

The Institutions of Mechanical and Electrical Engineers :

Here also the interviews were very satisfactory and the Secretaries promised to look into the matter if we were to draft a suitable representation to the Institutions forwarding them copies of the syllabus and question papers, together with the names of examiners, etc. for their perusal.

I should therefore request the Council to prepare a proper representation for submission to the three Institutions. I would suggest that all the correspondence in this connection should be carried out directly by our Institution and not through the London Branch, who, however, should be informed of the action taken by the Council in the matter.

The Annual Dinner was held at the Town Hall. The chief guest was Sir Akbar Hydari, P.C., D.C.L., LL.D., President of the Executive Council of His Exalted Highness the Nizam.

The members visited the sewage disposal works and farm at Amberpet, improvement works, poor houses and concrete roads in the city, filter beds at Asafnagar, the Himayatsagar, Osmansagar, Pocharum and Alisagar Lakes, Nizamasagar Dam and the sugar factory at Bodhan.

Dr. Korni's paper "Impact for bridges" was discussed and Nawab Ahsan Yar Jung Bahadur gave a lecture on "Hydro-electric power resources of the Hyderabad State".

11. EXAMINATIONS.—The Preliminary examination was not held this year as there was no candidate. The Associate Membership examination was held in March 1938. 23 candidates appeared in Section A, 8 passed ; 24 candidates appeared in Section B, 7 passed ; only one candidate appeared in Section C and he passed.

12. PAPERS.—The following papers were accepted as Institution papers during the year :—

	Subject.	Author.
(1)	Concrete Roads and the Bullock Cart ..	T. R. S. Kynnersley, A.C.G.I., M.I.E. (Ind.).
(2)	Lacey's Theory and the Deccan Canals ..	Rao Saheb N. S. Joshi, B.E. (Civil), A.M.I.E. (Ind.).
(3)	Bonded Brick Concrete Roads, Plain and Reinforced.	A. K. Datta, B.E., C.E., M.I.E. (Ind.).
(4)	Dehra Dun Water Supply—Bandel Nadi Extension.	H. G. Trivedi, A.M.I.E. (Ind.).
(5)	Engineering in the Indian Paper Industry ..	A. R. Beattie, M.I.E. (Ind.).
(6)	Tentative Hypothesis on the Nature of Friction with its bearings on Engineering questions including flow of water.	S. B. Joshi, B.E. (Civil), A.M.I.E. (Ind.), Advocate (A.S.) Bombay and R. N. Joshi, B.E. (Civil), A.M.I.E. (Ind.).

13. HONOURS.—Honours were conferred on the following members :—

Mr. Ramani Mohan Sinha	..	Rai Bahadur.
,, Surendra Kumar Guha	..	Rai Bahadur.
,, P. S. Viswanathan	..	Rao Sahib.
,, G. S. Ram ..	..	Rai Sahib.
,, N. S. Joshi ..	..	Rao Sahib.
,, M. A. Rangaswamy	..	Rao Sahib.

14. DONATION.—Donations were received from the following members as noted against each :—

Mr. A. K. Modi, Member	..	Rs. 25/-
,, K. R. Bhide, Associate Member	..	Rs. 25/-
,, H. A. Doctor, Associate Member	..	Rs. 10/-

15. ACCOUNTS.—A copy of the audited accounts for the year is appended.

The Institution of Engineers (India).

Balance Sheet as at 31st August, 1938.

LIABILITIES & SUNDRY CREDIT BALANCES.

	Rs. A. P.	Rs. A. P.	Rs. A. P.
Permanent Reserve Fund—			
As per last Account		1,03,276 14 3	
Add : Entrance Fees	2,200 0 0		
Composition Fees	2,394 0 0		
Transfer Fees	56 0 0		
Transfer from Income and Expenditure Account	2,866 8 0	7,516 8 0	1,10,793 6 3
(*Vide* Resolution No. 20 of Council Meeting No. 192.)			
Donations			3,778 7 7
Funds—			
Building Fund—			
As per last Account	80,553 15 2		
Add : Amount received during the year	60 0 0	80,613 15 2	
Sir R. N. Mookherjee Memorial Fund—			
As per last Account	1,476 6 3		
Add : Amount received during the year	657 5 0	2,133 11 3	82,747 10 5
Liabilities—			
For Expenses		1,020 0 0	
Viceroy's Prize		500 0 0	
B. E. S. A. Allowance Fund		1,481 15 6	
National Electro-Technical Committee for India		83 4 2	3,085 3 8
Advance Payments—			
Subscriptions		887 10 0	
Examination Fees		120 0 0	
Sundries		36 0 0	1,043 10 0
Employees' Deposits—			
Current Account with Imperial Bank of India (as per Contra)		100 0 0	
Post Office Cash Certificates (as per Contra)		1,059 0 0	1,159 0 0
Carried over		Rs.	2,02,607 5 11

ASSETS & SUNDRY DEBIT BALANCES.

	Rs. A. P.	Rs. A. P.	Rs. A. P.
Building—			
As per last Account		80,130 10 6	
Less : Depreciation—			
As per last Account	11,945 12 6		
Provided this year	2,003 4 1	13,949 0 7	66,181 9 11
Furniture and Fittings—			
As per last Account	22,952 4 10		
Additions during the year	1,395 5 0	24,347 9 10	
Less : Depreciation—			
As per last Account	9,863 5 1		
Provided this year	732 10 9	10,595 15 10	13,751 10 0
Stock of Stationery—At Cost			154 8 0
Book Debts—(Unsecured)—			
Subscriptions considered good		4,852 5 10	
Subscriptions considered doubtful		2,532 1 0	
Sundries		447 15 5	7,832 6 3
Advances—			
Recoverable in Cash			210 8 0
Permanent Reserve Fund—(As per Contra)—			
Investments—At cost—	Rs. A. P.		
5 % Loan of 1939-44 for	67,800 0 0	63,348 2 0	
4½% Loan of 1955-60 for	14,000 0 0	13,228 5 0	
4 % Loan of 1960-70 for	18,200 0 0	20,063 4 0	
3 % Bond of 1941 for	9,000 0 0	9,273 5 0	
	1,09,000 0 0	1,05,913 0 0	
Note : Market Value as at 31st August 1938—Rs. 1,16,509-12-0			
Cash with Imperial Bank of India on Current Account—			
Capital Account	1,893 6 0		
Revenue Account	2,987 0 3	4,880 6 3	1,10,793 6 3
Carried over		Rs.	1,98,924 0 5

	Rs. As. P.	Rs. A. P.
Brought forward		2,02,607 5 11
Library Deposits		25 0 0
Income and Expenditure Account—		
As per last Account	25,431 4 3	
Add : Excess of Income over Expenditure	4,070 14 7	
Adjustments referring to former period	61 5 8	29,563 8 6
	Rs.	2,32,195 14 5

	Rs. A. P.	Rs. As. P.	Rs. A. P.
Brought forward			1,98,924 0 5
Investments—			
4% Loan of 1960-70 for Rs. 25,100/- at cost		28,315 0 0	
Note : Market Value as at 31st August, 1938—Rs. 28,300-4-0.			
Post Office Cash Certificates deposited by Cashier Rs. 1,200/- at cost (as per Contra)		1,059 0 0	29,374 0 0
Interest accrued on Investments			1,645 13 0
Cash and other Balances—			
With Imperial Bank of India on Current Account—			
Revenue Account		1,114 8 11	
Employees Security Deposit Account (as per Contra)		100 0 0	
In hand		11 10 5	
With Local Centres—			
With Banks on Current Accounts	812 11 1		
In hand	213 2 7	1,025 13 8	2,252 1 0
		Rs.	2,32,195 14 5

AUDITORS' REPORT TO THE MEMBERS OF THE INSTITUTION OF ENGINEERS (INDIA).

We have audited the Balance Sheet of the Institution of Engineers (India) dated 31st August, 1938 and above set forth, and the annexed Income and Expenditure Account for the year ended 31st August, 1938 with the Books and Accounts as kept in Calcutta, in which are incorporated the certified returns from the Local Centres, and have obtained all the information and explanations we have required. In our opinion such Balance Sheet and Income and Expenditure Account are drawn up in conformity with the Law and the Balance Sheet exhibits a true and correct view of the state of the Institution's affairs according to the best of our information and the explanations given to us and as shown by the Books of the Institution. In our opinion Books of Account have been kept as required by Law.

PRICE, WATERHOUSE, PEAT & CO.
Chartered Accountants.
Registered Accountants. } Auditors

CALCUTTA,
19th November, 1938.

The Institution of Engineers (India).

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST AUGUST, 1938.

EXPENDITURE.

	Rs. A. P.	Rs. A. P.
To Salaries and Wages	15,004 0 3	
„ Postages and Telegrams	1,627 12 3	
„ Printing and Stationery	3,870 14 6	
„ Conveyances	181 15 3	
„ Rent and Taxes	6,159 0 0	
„ Lighting and Fans	434 5 0	
„ Journal	5,698 1 4	
„ Bulletins	863 12 0	
„ Issue of Papers	461 8 9	
„ Annual Meeting	723 14 9	
„ General Meeting	753 12 9	
„ Diploma	317 10 9	
„ Audit Fees	350 0 0	
„ Charges General	772 3 3	
„ Telephone	187 1 0	
„ Bad Debts	1,852 7 0	
„ Depreciations	2,735 14 10	
„ Repairs to Institution Building	721 0 0	
„ Legal Expenses	1,461 9 0	
„ Books and Periodicals	2,689 10 7	
„ London Committee Expenses	360 0 0	47,226 9 3
„ Balance being excess of Income over Expenditure transferred to Balance Sheet		4,070 14 7
	Rs.	51,297 7 10

INCOME.

	Rs. A. P.	Rs. A. P.
By Subscriptions		47,304 6 5
„ Interest	5,825 4 1	
Less: Transferred to Permanent Reserve Fund	2,866 8 0	2,958 12 1
„ Examinations		473 13 0
„ Sale of Standard Specifications		505 10 1
„ Sale of Publications		54 14 3
	Rs.	51,297 7 10

PRESIDENTIAL ADDRESS

BY

Mr. E. J. B. GREENWOOD

PRESIDENT 1938-39.

Gentlemen,

The Council of the Institution, as your representatives, have elected me to be your President for the ensuing year and I should like first to express my thanks for the honour conferred on me. The honour carries with it a substantial measure of responsibility and my distinguished predecessors have created a standard of industry and wisdom which I can but strive to emulate. It is particularly gratifying to my sense of pride, and I trust excusably so, to have my name coupled with that of the distinguished engineers who in the history of the Institution have occupied the responsible and onerous position of President. Fortunately the tasks involved do not fall on the President alone. He is helped and advised by a Council and its various Committees of men long experienced and skilled in the engineering arts, and by a secretariat whose efficiency has stood the test of many years of service. I can only say I shall do my utmost to uphold the high traditions of the office and to endeavour to push forward the interests and activities of the Institution and its members. As must have been the case with previous Presidents, I find time the most valuable matter in existence; as one grows older there is more and more to do and inevitably never sufficient time to do it.

The Institution born in January 1919 was formally inaugurated in February 1921 and I may add I was fortunate enough, as a representative of Madras, to be a member of the original Organizing Committee and later to attend in Calcutta that inaugural ceremony presided over by Lord Chelmsford, Viceroy and Governor-General of India. In subsequent years

I have been fortunate enough to attend the various annual meetings of the Institution until the last few years when pressure of official work has prevented my taking the long journeys inseparable from an institution which holds its annual general meetings at different places throughout a country which in itself is an empire.

The membership now is 1,472 after nearly 18 years of steady work. I am not going to say it is inadequate but I do affirm that we represent the main body of engineers in India. The Institution is securely founded and the grant of a Royal Charter in 1935 by His Majesty the King-Emperor has definitely given us a recognized place in the engineering world. I would do nothing to accelerate the membership of the Institution. I would eschew all schemes which have the sole object of increasing our membership to the detriment of the standard laid down in our charter. Membership of the Institution is the hall-mark of a qualified engineer; it is an honour not lightly bestowed; the standard is set by our charter and—unless we are false to the trust so placed in us—that standard cannot be reduced. I fully admit that in the changing conditions of our engineering development in India some changes in our charter will inevitably and gradually become necessary and I see no reason why we should not from time to time petition His Majesty The King-Emperor through the concerned Committee of his Privy Council to that effect; our charter is recent, 1935 and so it is unlikely that the changing conditions warrant any worthwhile petition for many years yet. I am glad to note a growing number of members anxious to effect improvement in the activities of our Institution and, subject to our Bye-Laws read together with clause 20 of our charter, there can be no possible objection to improvement; I would beg those keen members to pursue their aim in all friendliness and patience. The Institution has for many years been the Indian Committee of the British Standards Institution and of the International Electro-Technical Commission.

I view with mixed feelings the attempted growth in India in recent years of kindred institutions of an engineering nature; the fold of our own Institution is wide and our membership includes distinguished representatives of all branches of engineering and its allied sciences. It is conceivable and will inevitably occur that our Institution will form special sections to deal with

subjects such as railways, irrigation, water supply, electricty, reinforced concrete, where concentrated discussion on those subjects can take place. All such sections however, will remain integral parts of the Institution and we may visualize a state in the future when our Institution consists entirely of such sections controlled by, I trust, an unenlarged but truly representative Council.

The coming year may see some progress in the setting up of a standardising institution and possibly some move forward in the matter of an Engineers' Guild or Register. I am uncertain that our interests will be improved by an Engineers' Guild or Register. It seems inevitable that the economic status of our profession will, by the application of a reasonable degree of commonsense and initiative, take care of itself. It cannot be denied that the profession as a whole has done reasonably well as compared with the other recognized professional callings. The formation of a register if carried out on broad lines may prove of benefit to the public at large as at present many public bodies have inadequate understanding of the canons of tendering, the niceties of technique and the execution of competently engineered works. I feel strongly that legislation is the last thing we desire or require to uphold our profession. As voiced by our N. W. of I. centre, members can do much more for themselves and for the profession in general by being more particular in their selection of staff, contractors and patronage.

The preparation and presentation of papers to technical institution is of great importance to the profession but we can and should do more than that. I think engineers should be more publicly assertive and by articles and letters in the Press lose no opportunity to educate the public in the economic value of sound engineering. Erroneous statements concerning engineers and their works should be challenged and the omission of suitable mention of engineers when important works are being opened or described should be protested against. Retired engineers and those who can afford the time should participate in local affairs by becoming councillors or members of local boards. At present local administration is mostly in the hands of lawyers, schoolmasters, doctors and other public spirited persons; engineers might well follow in their footsteps. The

status of the engineer would be so much improved by some check on the inadequate salaries now offered and perforce accepted; such pittances recoil disastrously on the standard of the profession.

In the present stage of this country in so far as its material progress is concerned we as engineers should, I consider, strive for its industrialization. I am not unmindful of civil engineering progress in the fields of railways, harbours, irrigation and water supply or of electrical engineering progress in its hydro-electric and thermo-electric power stations and vast distribution systems, but such works are only a means to an end and that end in the eyes of the world is manufacture and the international trade arising therefrom. We cannot rest content—admirable though the design and execution of the works and their benefits may be—with the construction and operation of irrigation and water supply systems and the improvement in the lot of our vast agricultural population: we must press for more industrialization, for in industrialization alone lies the key to the problem of raising the standard of living of the peoples of this country. In my opinion no nation can develop its vitality and well-being by an existence entirely within its borders: it must by exports and imports range itself in competition with the other nations of the world and so establish its place and pride of existence.

There can be no gainsaying the relative importance of the engineer in the universe as an ordered whole. In India much emphasis and attention is paid to the lot of the agriculturist; and about him I would like to digress for a moment. The plough of the agriculturist is rapidly becoming steel shod: what a wealth of industry and engineering ability that ploughshare with its fixing screws or nails envisages! Mining, winding engines, steel works, railways, machinery and so on. Even the agriculturist's loin cloth has practically no being except through machinery; I understand the great majority of Khaddar is made in modern power mills. For its food, clothing, furniture and every single need the world is entirely dependent on machinery and the engineering profession. We need not and do not lose our sense of proportion however: every walk of life, whether labourer, administrator, doctor, physicist or soldier has his place and pride of place.

India has been slowly but surely advancing in the realm of manufacture: apart from agricultural materials such as cotton, jute, sugar, tea, wool, leather, we have a number of important works for the manufacture of iron and steel, paper, chemicals and in more recent years for the manufacture of machinery, bridges and the like. In fact the last few years have witnessed a considerable advance in the industrial progress of the country. Since the stimulus given to industries by the labours of the Industrial Commission there have been in the last 20 years a considerable change in the relative importance of the different classes of industries in India. As viewed from the number of persons employed cotton and jute still remain our major manufactures, although jute has practically stood still, but recent years have seen the enormous growth of the sugar, tea, cement and match industries, while the expansion of engineering works including railway workshops has been most marked. Most welcome is the attention and study now being given to the intensive utilization of our hydro-electric and mineral resources as distinct from the agricultural. Excluding coal and petroleum, I am afraid economic considerations will mitigate much utilization of our mineral resources unless heavily supported by import tariffs or until large blocks of very cheap hydro-electricity become available; the commercial manufacture of basic chemicals and the smelting of our metallic ores cannot be undertaken in small factories. Too often in the selection of sites for factories is the importance of the water supply overlooked; considerations of the distance from the factory of one or more of the principal raw materials including the fuel or the power and the distance to the market or to the port for the finished product are rendered void if the water supply is inadequate in both quality and quantity not only for the process of manufacture but also for the labour force attracted to the locality; in some cases the effluent from the factory is also a matter of most serious consideration.

Manufacturing progress has been slow but very sure. Every factory has its own methods and details of manufacture, and some are rightly secret. There is however a great necessity for the writing of papers on industrial subjects and for recording the various methods and details so that industry may advance by knowledge of the past and of its avoidable mistakes. I would like to see the papers presented to the Institution deal

more with the industrial application of engineering than with engineering science itself. Every manufacturing works contains some nucleus of research not necessarily in apparatus of a testing nature, but in experimental processes. While the majority of firms cannot emulate the Tata Iron & Steel Works at Jamshedpur, whose large laboratory solely for metallurgical research is a clear indication of the great commercial benefits of research to that industry, a great deal more could be done by the leading firms in the other industries. Our educational institutions in the last ten years have not rested content with importing knowledge, but have set up equipment with facilities and men to carry out research.

In our everyday life there is considerable interdependence between the engineer, physicist, chemist, doctor, biologist and the like. There is no public utility where in the processes or working carry on without the universal spread of specialist knowledge. A water supply works is a good example of the interdependence of the geologist, engineer, chemist, doctor and many others. Our best engineering cannot be done by engineer specialists except as these have a sympathetic and respectful appreciation of the work of other and equally important specialists and will work in co-operation with them. The physicist in particular is becoming increasingly responsible for much research work for the benefit of the engineer : in fact without the physicist there could be little advance in the engineer's design practice. I have in mind the advances in the composition of steel and the ways of adapting it to meet the engineer's needs in utilizing higher steam pressures and temperatures, in dealing with difficult water conditions or in materials subject to rapidly repeated stresses.

I wish to include in this address the subject of the education of the younger members of our profession. It is becoming increasingly recognized that there should be no specialization in the school stage, that what will prove best in after life is a high standard of general education in what I will term the cultural subjects like English, French, and Pure Mathematics together with may be some leaning to the pure sciences of say Physics and Chemistry; many prominent engineers consider that without good participation in the corporate life of the University an engineering degree is shorn of much of its value as an adequate foundation for an engineering career.

In other words the best foundations are primarily the ability to think and to apply principles rather than technical knowledge and secondly the development of personality and ability to mix, handle and control men and not machines. In some quarters already, for example the recruitment to the Civil Service in India and to the P.O. Engineering Department in England, it is realized with practical effect that the examination system is not the only or even the best guide of ability. As it is not possible to make any rapid change in this matter and also I cannot pretend that such universality of opinion has yet been reached I do think we should make some early move to improve the position. I consider that, while there can be no lowering of the standard of intelligence required to obtain a University degree in engineering, there should be a considerable overhaul of all syllabuses to reduce the volume of work so as to be able to emphasize the fundamental principles of engineering science and the proved mental ability to apply those principles. The hall mark of an engineer is not merely theoretical training but sound ability to apply that knowledge to the principles of engineering science out of which only can true knowledge of the subject grow and have its being.

My plea for an overhaul of examination syllabuses does not overlook the fact that every year as a result of research in the properties of materials and in the means of measurement our knowledge of the principles of science is being enlarged. This inevitably means an enlargement of syllabuses dealing with the applications of engineering science. Unfortunately there can be no enlargement of the already long terms of collegiate study; with the speeding up of commerce by the more rapid means of communication and transport I think that it is unwise to lengthen the period of academic study beyond the present 3 or 4 years. Hence I repeat we must from time to time overhaul every academic syllabus to keep it within the human capabilities of an unlengthened period of study. In this connection I would remind you that our Institution has been successful in raising the standard of training and examination of several universities: further in recognizing the courses of

training and examinations of kindred engineering colleges and institutions our Institution has ever kept in mind the standard laid down in our charter: and while accepting some examination tests it has declined to accept many of lower standard.

The education of the younger members of our profession does not rest solely on engineering examinations by educational or even institutional authorities; it is necessary for those of us in a position to arrange matters to provide facilities for practical training in the various branches of each undertaking. Industry in India is carried on in small undertakings; the average daily number of persons employed in our heaviest industry, jute spinning and weaving, is under 4,000 in a single factory. The volume of our large-scale undertakings such as dominate the industries in Europe and more particularly U.S.A. is very small considering the immensity of our population. I presume no one will challenge my stating that we shall make little advance in the industrialization of the country without the setting up of large scale undertakings. I do not decry the field of cottage industries but I maintain that their economic value to the State is comparatively minor. It is impossible to initiate and carry out industries on a large scale unless there is an adequate supply of men specially trained for the direction and management of large industrial concerns. The much desired advance—and there is no denying there is ample scope for the setting up of large scale industries—would be assisted by each industry affording greater facilities to train its own recruits. Many of the larger undertakings already afford facilities for the training of their work people and particularly the younger members but in the broader view the need is for the training of the supervisory grade out of which would rise the directing and managing grade for those men with an adequate background of higher education, general and professional.

I would like with your permission to finish this my address on an individualistic note emphasizing that engineering in

its designs, execution and progress depends entirely and for always on the man. Kipling epitomized the point in the lines :—

"The careful text-books measure
  (Let all who build beware)
The load, the shock, the pressure
Material can bear.
So when the faulty girder
Lets down the grinding span,
The blame or loss or murder
Is lain upon the man.
Not on the stuff but upon the man."

THE NINETEENTH ANNUAL DINNER.

The Nineteenth Annual Dinner was held at the Mint House of His Highness the Maharaja of Benares on Saturday, the 14th January, 1939.

His Highness the Maharaja of Benares, who was the Chief Guest, was unfortunately unable to be present owing to sudden illness.

Khan Bahadur Maqsud Ali Khan, proposed the toast of His Majesty the King-Emperor, which was duly honoured.

In proposing the toast of His Highness the Maharaja of Benares, the President said :—

Ladies & Gentlemen,

Before proceeding to my most pleasant duty to propose the health of H. H. The Maharajah of Benares I must express on behalf of the members of the Institution of Engineers (India) our deep regret at his absence this evening by sudden illness. I would ask his Chief Secretary with us here, Khan Bahadur Maqsud Ali Khan, to convey to His Highness our sincere sympathy and trust that he will soon be restored to health. We are honoured by his so kindly and readily placing this fine building at our disposal for this function. We regard our Annual Dinner as an important function giving members brought together from far-flung parts of this vast country an opportunity to leaven our engineering papers, discussions and visits to works with that great act of personal friendship, the partaking of a meal together and in company with guests distinguished in all walks of life. His Highness is the first ruler of an Indian State to be our chief guest and to my mind that is a happy augury of the joint progress of engineering in both British India and the Indian States. Already the Indian States show mighty leadership in the world of engineering, for example,

Hyderabad, Mysore and Kashmir have works connected with irrigation, railways and electric supply of the first magnitude. Although Benares was a Kingdom from time immemorial—its fame finds record in ancient Hindu and Buddhist literature —it is only within the last thirty years, in 1911 I believe, that the ruler has had power to develop the State on modern lines. In relation to its revenue and population His Highness' State has now a most progressive engineering record and particularly in the field of canal irrigation. The members of our Institution assembled for this annual meeting have already seen much of the engineering and industrial activities of the neighbourhood and we look forward with interest to the remaining visits before this meeting terminates and we disperse to all parts of India. Those of us with historic and archaeological leanings look forward with the keenest anticipation to our visits tomorrow to Sarnath and on Monday to His Highness' capital of Ramnagar and particularly to his palace, permission to view which is a further instance of his kindness to us. I now call on the members of the Institution to charge their glasses, to rise and to show their hearty appreciation of H. H. The Maharajah by drinking his health and wishing him restored health, and also happiness and long life in the service of his State.

In reply to the toast Khan Bahadur Maqsud Ali Khan read out the following speech of His Highness the Maharaja of Benares :—

Mr. President, Ladies and Gentlemen,

I thank you, Mr. President, for the reference that you have so kindly made in your speech to myself and to the engineering activities in my State. It has given me great pleasure indeed to be your guest at this annual function of your Institution, which has rendered such valuable services to this country during the 18 years of its existence.

To you Mr. President, the Institution is indebted for the keen interest that you have been taking in its progress over a long period of years, being its member from the very beginning. The Institution is no doubt fortunate in having you to guide its affairs this year.

We all know that engineers have at all times played a very important part in the development of the resources of their respective countries and in contributing to the material

prosperity and cultural advancement of their people. It is the engineering science to which we owe mainly the industrial progress that we see all around us in the world these days. Engineers are undaunted fighters against nature and it is they chiefly who have been privileged to harness the forces of nature to the service of man both for his material and aesthetic advantage.

The magnificent buildings, the wonderful bridges, the modern facilities of communications, the turning of waste land into cultivation and the great achievement of the mechanical and electrical systems which are in evidence on all sides, are, all of them, the result of the labours of engineers. In fact, in daily life in the cities one can scarcely escape being reminded of the existence of the engineer throughout the 24 hours.

Your Institution, which is representative of all the branches of engineering, and which enjoys the high distinction of possessing a Royal Charter, is undoubtedly a boon to the country. By your annual meetings you provide opportunities for exploration of fresh fields of knowledge and for the exchange and evolution of new ideas on different aspects of the engineering science, which keeps you abreast of the times.

It was a happy thought which made you select Benares to be the venue of your annual meeting this year. As we all know, Benares is a very old and interesting city, and among its beautiful riverside buildings and ghats and more modern works of engineering interest, you will no doubt find some places which will engage your attention. The ancient Budhistic monasteries on one side of the city and the up-to-date buildings of the Benares Hindu University on the other side, will also, I am sure, well repay the trouble that you will take to visit them.

I am also glad to notice that the Hewett Dam at Latifshah over the Karamnasa river in my State is included in your programme of visits and I hope you will find your visit to that spot enjoyable. This work and most of the other engineering works in the State have been constructed by qualified State Engineers who had been mostly recruited from the engineering services in British India from time to time.

In the end let me wish your Institution a very bright and prosperous future.

In proposing the toast of "Our Guests" Raja Jwala Prasad said :—

Mr. Sathe, Ladies and Gentlemen,

It is so kind of you to express such warm sentiments for us and our Institution. It is said in Hindu Sankhya Philosophy that human ideas are but a changed form of the food energy assimilated by the body. How far this warmth of sentiments is due to the warm dishes served this evening might be left to the metaphysical analyst.

This is the first time that the Institution has held its annual meeting in this ancient city of Kashi. It is called the Bhumi or Land of Vishwanath, the Primal Lord of Phenomenal Creation. We, Engineers, are the direct disciples of Vishwakarma, the active material Agent of Vishwanath. A spiritual flight of ecstatic vision may easily take us to the dawn of humanity when Engineering knowledge was first unfolded here by Vishwakarma under the inspiring direction of Vishwanath.

Billions and billions of years may since have rolled till in 1919 a resplendent thought flashed into the minds of Senior Engineers to start this Premier Institution. Simultaneously with this the inception of a true Brahmin led to the establishment of an institution at Kashi which now supplies the bulk of our mechanical and electrical engineers. May we spiritually discern the Divine Hand of Vishwanath in thus inspiring the inauguration of this Karamyogie Institution simultaneously with the birth of our Engineering College to propagate its prospective workers. If I may so presume, this might well be the chief attraction which drew this year's Annual Meeting to this sacred city. May this ever increasing stream of the senior and budding disciples of Vishwakarma continue to flow, to the lasting and ever increasing prosperity of our motherland.

Engineers, as you know, have always been devoted servants of humanity, while the need of such service was never greater than to-day. Partly politically free, the little light that we now have only serves to make darkness more visible.

Industrially and economically we find ourselves in hopeless bondage of advanced nations—an aspect much more gloomy than even the Swaraj question. If the nation wishes to make itself free from this wholesale bondage, we must harness the clearest of Indian brains and the sturdiest of Indian patriotic hearts to put forth the requisite thought and effort. The country is at present on the threshold of a great renaissance and efficient engineers therein are a very vital factor.

As for defence, the less said the better. We have got millions and billions of human heads, but untrained in modern military engineering, both defensive and offensive, they are no more than so many helpless heads, to be mown down at the will of a ruthless trained enemy. Complete harmony between an engineering brain and an unerring limb are the *sine quo non* of engineering efficiency and these can only be secured by incessant education and precise practice. May we hope that the Powers That Be will give adequate importance to the engineering profession for the glory of the motherland to whom they are so passionately devoted.

Ladies and Gentlemen, I am afraid I am straining your patience to the breaking point and I must therefore close. Warmly thanking our friends for their sincere help and kindness, I ask you to heartily drink to the health of our Guests.

In responding to the toast of "Our Guests" Mr. J. L. Sathe said :—

Gentlemen,

I rise to thank our hosts for the sumptuous dinner which they have given us and in giving which I hope they have incidentally fed themselves also well but not too well. It is customary that when Brahmins are invited to dinner they are not only fed but a *dakshena* is given on the top of the dinner and our hosts have not forgotten to do that in the shape of the kind words which they have uttered about us.

When I first began to understand things as a child my idea of an engineer was that he was one who drove a railway engine *i.e.* an engine driver. Later on when I began to learn more things, one of the first lessons, which I got in saying one

thing while meaning another, was to call a man who built houses or roads an engineer. Apparently in those days free masonry must have been in great disfavour, for otherwise I do not see why a mason or an architect should have been ashamed of calling himself by his correct name and should have adopted the euphemism of engineer. I guess that if free masonry had half the status and reputation which it now has, we should have talked of a master mason instead of an Executive Engineer, a grand master mason instead of a Superintending Engineer and a master general mason instead of a Chief Engineer. But as it is, instead of having such sonorous and beautiful phrases we have to be content with humdrum appellations like Executive Engineer and Chief Engineer. Later as I grew older and my knowledge of engineers became wider I came to know that there were still other kinds of engineers—sanitary engineers; electrical engineers; water works engineers; irrigation engineers; sugar engineers; automobile engineers and so on. I do not know where this campaign of engineering aggression is going to end. Perhaps in course of time we may begin to call lawyers litigation engineers, journalists wastepaper engineers, priests marriage engineers and so on. It seems that we are in an age of engineers where it is the fashion for everyone in position to call himself an engineer of some sort. But I hope that in this age which is also one of unemployment the converse will not be insisted upon, *viz.* that no one who is not an engineer can be a man of position, for otherwise where will the rest of us all be?

But talking seriously I think that what India needs at present is capable engineers and more engineers. While the rest of the world is in the midst of the mechanical age, the greater part of India is still living in the mediaeval rural age in spite of the fact that the population is advancing by leaps and bounds. The result is that the pressure on land has become enormous and the only way of salvation for India seems to be its industrialisation. I am so convinced of this that I have given two hostages *viz.* my son-in-law is a sugar engineer and my son is going to be an automobile engineer.

Gentlemen, on behalf of the guests assembled here I wish all strength and prosperity to our hosts and thank them most cordially for inviting all of us to this pleasant function.

Mr. Mohsin Ali in reply said:

Mr. President, Ladies and Gentlemen,

I have a confession to make, and I hope it will bring you some relief. I am an Irrigation engineer, who has dealt all his life in water, but I assure you, when it comes to making a speech, I dry up. It is the privilege of the Irrigation engineer to live for 360 days in the year on the canal bank, out in the blue, like "Diogenes in the tub," and so, when he finds himself in polite society, and in the presence of an august body like this, he naturally feels shy. You need not therefore be perturbed that I shall inflict a long oration upon you. Wild horses could not drag me up a platform to address any audience, much less a learned audience like this, but to-night, I have some very pleasant duties to perform, so pleasant, indeed, that I feel persuaded to come out of my native shell just for once in my life. Naturally, you may be sure I shall be as brief as possible.

I have, first of all, to thank my old friend the Khan Bahadur Maulvi Maqsood Ali Khan Sahib, Chief Secretary of the Benares State, for saying what fine fellows we are, and for proposing the toast of the Institution. I am afraid we engineers are a great nuisance. We perpetrate hideous buildings, we build dusty roads, we charge exorbitant water rates, we waterlog the country, we are even responsible for the floods, we eat up large funds of public money, we electrocute innocent little boys and girls, we bring about train smashes, we even stage earthquakes in order to get fresh opportunities of jerry-building—in fact we are a necessary evil. It therefore did our hearts a lot of good to hear the kindly words which the Khan Bahadur put in for us, and, on behalf of the Institution, I have the privilege to thank him.

The Institution is also deeply grateful to His Highness the Maharaja Sahib of Benares for his gracious hospitality, and for placing the resources of his State at our disposal, so as to enable us to have a successful session in Benares. We are all very disappointed because, due to his sudden illness, he is unable to be in our midst this evening, and we pray he will

soon recover. As we all know, His Highness himself comes of an illustrious line of illustrious builders, who have transformed a poor famine-ridden undeveloped tract into a smiling country, waving with corn and other cultivation, by the construction of large irrigation projects, arterial and subsidiary roadways, and other works of public utility. It was therefore in the fitness of things that the Institution, in its peregrinations round India, should visit the State, and acquire a first-hand knowledge of the high water-mark of its engineering achievements, for which the Institution offers its deep appreciation to His Highness. For myself, I have the honour of having served the State some twenty years ago, when I was a very junior Executive Engineer. Also on behalf of those of us who are His Highness's personal guests, I offer His Highness our grateful thanks for his kind and generous hospitality.

The Institution also owes a deep debt of gratitude to Pandit Madan Mohan Malavyaji, the architect of the modern home of Hindu learning, for his warm and touching welcome to us. As I said the other day, in my address to the United Provinces Centre of the Institution, we, as a representative body of Indian engineers, ought to be particularly grateful to Panditji because, alone among all the universities of India, the first building which the newly-projected Benares Hindu University put up was the Engineering College. We therefore owe a special debt to him for having thus demonstrated to an unenlightened public that the profession of Engineering is an honourable profession, and is at least as necessary as any other for developing a sub-continent like India, and for raising its status amongst the most progressive countries of the world.

After Malavyaji, our thanks are due to his colleague and collaborator, Raja Jwala Prasad, the builder, and now the Pro-Vice-Chancellor of the Hindu University, and one of the past presidents of the Institution, for all the trouble that he and his staff have taken, and for all the care and attention they have bestowed to every minute detail, in making our annual meeting a success. We are proud to have him as our member, and the United Provinces Association owes not a little to him for his fatherly advice and help. Most of the United Provinces engineers have, at one time or another, come under

the spell of his charming personality, and particularly those of us who have had the privilege of serving under him will always have a loving corner in our hearts for him.

Lastly I would like to offer the thanks of the Institution to Rai Sahib Piare Lal, the Benares State Engineer. There is a saying in Persian— سگ باش. برادر خورد مباش "Be a dog but don't be the younger brother." He is the younger brother of the family, and on him has fallen the brunt of making many of the detailed arrangements for the annual meetings both of the United Provinces Centre and the parent Institution, and how well he has carried them out ! One and all we thank him.

I am not unmindful of my promise to be brief, but before I sit down, I must express the Institution's thanks to the City of Benares for its hospitality and welcome. With Benares, this hospitality is traditional. Ever since the dawn of history, pilgrims from the four corners of India have flocked to its holy banks. Men and women in all stations of life, men of learning and beautiful women and the common folk have all been welcome. It received the Lord Budha with open arms. شیخ علی حزیں , a great nobleman of Persia, and one of its greatest poets, found shelter for his wearied bones and his persecuted soul in holy hospitable Hindu Benares, and this Moslem poet from across the borders has enshrined his appreciation of the beauty of the spirit of Benares in some of the noblest lines of poetry, which will always be remembered so long as Persian poetry is read for its musical quality, and so long as Benares reigns as the queen of the Ganges, attracting the fairest of the fair from all parts of India.

ADDRESSES OF CHAIRMEN OF LOCAL CENTRES.

Speech by Nawab Ashan Yar Jung Bahadur, C.E. (Cooper's Hill) M.I.E., (India), Chief Engineer and Secretary to Government P.W.D. (Irrigation and Drainage) on the occasion of the Inaugural Meeting held on the 15th of November 1938, at the Town Hall, in connection with the formation of the Hyderabad Centre of the Institution of Engineers (India).

Your Excellency & Gentlemen,

I have great pleasure in welcoming your Excellency and all the brother-officers most heartily to this meeting for the inauguration of a local centre of the Institution of Engineers (India).

It will not be out of place on this occasion if I briefly acquaint you with the history of this great Institution.

More than a century ago Engineering was defined as the art of directing the great sources of power in nature for the use and convenience of man. This was the ideal that inspired the formation of the Institution of Civil Engineers in Great Britain. With the advance of time and progress of science the scope and utility of the profession has increased all over the world.

India with its large number of Engineering works and a large body of Engineers engaged in civil, mechanical, electrical and industrial branches, was urgently in need of an Institution where the day-to-day problems arising in connection with the works in the different parts of the country could be discussed and their solutions crystallized for the benefit of the profession and the advancement of science.

Thanks to the endeavours of several distinguished Engineers in the country, the Institution was established in 1920, and granted a Royal Charter in 1935. In this connection we

cannot but gratefully remember the names of Sir Thomas Holland, Sir Thomas Ward and Sir Rajendra Nath Mukherjee and their colleagues who rendered yeoman service in founding the Institution.

The names of Lord Chelmsford, Viceroy of India and Sir Stanley Jackson, Governor of Bengal, will always be most gratefully remembered for their interest and help in the establishment of the Institution of Engineers.

It seems a strange coincidence that the Institution should have seen its birth in Calcutta, where you all know the first University in India was established. Just as the establishment of the several Indian Universities was followed in the course of time, the Institution of Engineers has also expanded and I am glad to say that the branches of the Institution have been established in the United Provinces, Bombay, Madras, Bengal, North West Provinces and Mysore.

It may, therefore, be regarded as a red letter day in the history of Engineering profession in Hyderabad that we have all assembled here to see the inauguration of the local centre of the Institution of Engineers.

Gentlemen, since I was elected to the Institution as a member many years ago, I have all along desired to establish a local centre of the Institution for the Engineers of H.E.H. the Nizam's Dominions. This wish of mine, I am thankful to the Almighty, has now been fulfilled and the Council of the Institution has consented to our forming a local centre at Hyderabad.

We are singularly fortunate in having the opportunity of the inauguration being performed at the hands of His Excellency The Rt. Hon'ble Sir Akbar Hydari, whose statesmanship has been responsible for the creation of numerous institutions for the advancement of education in our country, the most important among them being the Osmania University. We are confident that, blessed at his hands, the Institution will grow in usefulness for the service of our craft and country.

We are on the threshold of large Engineering works. The great Engineering Schemes such as the Tungabhadra, the Godaveri and several others which we are contemplating for Irrigation and Hydro-Power will need the best of talents,

and I am confident that the formation of a local centre will go a great way in fostering the growth of Engineering interest in our young men, and bring out the best of results in the service of our State.

The formation of a local centre at Mysore in the year 1936 has given a great impetus to the technique for industrial development in the State and I sincerely hope that we shall also become a source of technical information necessary for rapid industrial development in our State.

I now request Your Excellency to proceed with the inauguration of the local centre of the Institution of Engineers at Hyderabad and bestow on us your very good wishes.

Address by H.E. The Rt. Hon'ble Nawab Hyder Nawaz Jung Bahadur, P.C., Kt., B.A., LL.D., President H.E.H. The Nizam's Executive Council, on the occasion of the inauguration of the Local Centre of the Institution of Engineers (India) at Hyderabad on the 15th of November, 1938, at the Town Hall.

Let me thank you, for the cordial expression of your welcome to me to-day, and let me assure you that it is a very great pleasure to be present among this gathering of Engineers and to have the privilege of inaugurating the local centre of the Institution of Engineers in India in this State.

I retain very pleasant memories of the last Session of your Institution in this historic City, when, at the annual dinner I was able to meet many of your members from all over India and thus to obtain a more direct and more personal acquaintance with the activities of your institution than I had previously enjoyed. I remember that I had then assured you of the warm interest that I would retain in the growth and fortunes of your Institution. It, therefore, affords me keen pleasure that it should have been possible in the course only of a year for me to be associated with this very significant extension of your activities.

No one can doubt the usefulness of an institution such as yours. It is recognised on all hands that the material advancement of any country is in no small measure dependent on its Engineers. But, I feel that for an Engineer to be successful,

it is necessary that he should keep himself abreast of the times and adopt modern methods, evolved out of the latest researches, in the design and execution of works. Many of you must have seen works which could have been simplified in design and construction, and reduced in cost, by studying the difficulties met with by others and how they had been overcome. Institutions such as yours, whose object is the collection and dissemination of the latest knowledge for the advancement of the profession are, therefore, of inestimable value.

This brings to my mind that these are days of specialization and one of the most keenly felt wants is some means whereby knowledge on a particular subject can be gathered in a conveniently comprehensive form. Having regard to the many sided development of the Engineering activities of our State I trust that the establishment of this centre will enable you to collect and distribute the data and material necessary for solving problems concerning the different works that you may have to construct. It must be remembered that dealing as you do with the sources of power in nature, it is necessary that you should study Nature's Laws as closely as possible.

It is the duty of all of us who are engaged in promoting the moral and material welfare of India to develop as rapidly as possible the great resources of the country and thus give to many of our young men with ambition and enterprise a further outlet than the rather limited choice which they have at present. Considering the possibilities of development which still lie before this country and the demands which the expansion of Industry may be expected to make in future, there can be little doubt that there will be an increasing need of Engineers—for Engineers who are able and efficient according to the latest standard of the profession.

Among the problems which concern the essential requirements of a modern community are means of communication, by road and rail, and the supply of water to raise food and commercial crops. We are aware of the enormous road traffic existing and ever increasing. One of the serious problems to be solved by road engineers is how to make a safe road surface at an economical cost, just as the Railway Engineer has to consider how best to provide a track that will be at once safe and economical for the transport of passengers and mer-

chandise, and the artist in your profession has to show how the road or track will be beautiful so as to satisfy our aesthetic requirements.

Schemes for the utilization of the natural water resources of this State have been receiving the consideration of the Government of His Exalted Highness, during whose reign numerous Irrigation Works, some of them of outstanding importance, have been carried out. For schemes of this kind the State requires Engineers of undoubted ability. These are considerations which should provide food for thought and I am sure that the inspiration which you will derive from this Institution will enable you as the exponents of science to search for new and sound ideas for your future work.

I must also draw your attention to the aspects of aeronautical and wireless Engineering which are rapidly gaining a place of high importance in the scheme of human progress. We have not ceased to marvel at the remarkable progress made during the last century in commerce and communication with distant countries ; the introduction of new and rapid means of transport, the greatest of all marvels, the power to communicate by speech through no visible medium from one extremity of the world to the other, and even with the ships at sea, and to aeroplanes in flight. We may well consider, therefore, the wide possibilities of further development which Engineering science offers for the future. On the Scientist and Engineer the developments of the future will in the main depend. And we all have the fullest confidence that, as in the past, so in the future, the skill and resource of your profession, according to the definition given by your President in his address of welcome "will direct the sources of power in Nature to the use and convenience of man."

Let me give you a word of advice before I conclude my address. The Engineer of the new epoch must sink the individual in the profession. The Engineering work of the future must be better work than has ever yet been done. The best work is rarely if ever done by separate men. It can only be accomplished when professional knowledge so permeates all members of a profession that the work of one is virtually the work of all. I strongly urge you to bear this in mind as members

of the centre which is now being formed. The success of the centre and its usefulness will depend on the sustained effort of its members to make it so. Without interest, enthusiasm and co-operation the centre will not only cease to be useful but will be indicative of the absence of initiative and unity among you and a discredit to Hyderabad Engineers. Each one of you to-day is undertaking an obligation to make this centre a genuine success.

It is now with the greatest pleasure that I declare this local centre open, and I have the fullest confidence that it will, in the richness and fulness of time, be of ever increasing usefulness to our country. I wish to assure you that I shall be keenly interested in your activities and will be delighted to see not only that you gain the knowledge of others, but that you contribute something of your own to the general advancement.

Address delivered by Mr. H. P. Bhaumik, O.B.E., at the Eighteenth Annual General Meeting of the Bengal Centre held in Calcutta on the 9th December, 1938.

Gentlemen,

It is my first duty to convey my sincerest thanks to the members of the Committee of the Bengal Centre for having elected me their Chairman for the ensuing year. No one knows better than myself my limited capacity for discharging the duties of this responsible office. I can only say that with the help and co-operation of the Committee I shall try my best to advance the cause and promote the ideal for which this Institution stands.

Gentlemen, I had the honour of serving the Committee as their Honorary Secretary for the last twelve months. The activities of the Centre during this period have been detailed in the Annual Report which is now before you. I wish we could do more in this period than what has actually been achieved. As in previous years, we found it rather difficult to get our members write papers on Engineering subjects and read them at the General Meetings which are held from time to time. Many of our members who are in a position to help us in this direction, were unable to do so for a variety of reasons.

Some of them were so busy with their professional duties that they could not make time to write papers for the benefit of their fellow-members of this Institution. Others probably hesitated because they thought that their contributions would not be of the required standard. I tried to persuade several eminent Engineers that what was wanted was not always the result of original research, but an account of their experience in the various spheres of Engineering in which they took part. I even invited them to give us talks on various Engineering problems which they may have dealt with during their day-to-day work, if they found it inconvenient to write formal papers. I have to admit that my efforts did not produce the desired results. I consider that the talks and discourses referred to above will be of the greatest value to the members of the profession and will materially assist in spreading Engineering knowledge which is the main function of this Institution. I hope, Gentlemen, we shall obtain a better response from our members in this direction during the ensuing year. Professional papers, discourses of engineering problems of various kinds and the narration of one's practical experience in carrying out important Engineering projects will always be welcome. None need hesitate to come forward and render us necessary assistance from an erroneous notion that nothing which is not original or very striking, is worth being described to their fellow-workers who are members of this Institution.

We have paid several visits to Engineering works in Calcutta and its suburbs during the year. The attendance in these visits has on the whole been satisfactory. Here again we found that many senior members refrained from joining the parties. This is not as it should be. I consider it is the duty of the seniors to accompany the younger members in these visits. Their presence is an encouragement to the others who will derive great benefit by their guidance and where practicable, by the elucidation and explanation of the various Engineering processes of which they may have practical experience.

The visits were all very interesting. I would however make special mention of three among others. The visit to the new Howrah Bridge Works was of outstanding interest as was evident from the large number of Engineers who took

part in it. It is a very important Engineering project and first of its kind in Bengal. It is also of interest to note that local products and materials are being used in this work to the fullest extent practicable.

This visit to the Bengal Lamp Works was also of great interest. This industry seems to have a bright future. As a matter of fact, more than one such factory *on extensive scale* run on judicious lines, ought to be established in India. The demand for lamps of different types is very large indeed, and at present the local produce is only a small fraction of the total requirements.

The Alipore Test House was another institution which was also visited during the course of the year. This Institution is doing very important work from the practical engineer's point of view and it ought to be of great assistance in standardising engineering practices in many spheres. I might mention that the lack of standardisation of Engineering practices and methods with reference to the special needs of this country is not infrequently felt by many engineers. It is very desirable that systematic work in this direction should always be encouraged by experienced Engineers and this Institution ought to take an important and leading part in this direction.

Gentlemen, the function of an Engineer has become more or less all embracing now-a-days. Time was when the profession of an Engineer was considered to be of minor importance and the Engineer used to be given a comparatively lower status among members of the so-called learned professions. This has now changed for the better and the world has taken a different view of the matter. America and Germany have given a definite lead in this respect. It is not uncommon now-a-days to find Doctors of Science engaging themselves in the design and planning of machines, tools and apparatus of all kinds in different spheres of Engineering. Engineering research work is absorbing a fairly large number of educated men holding high university degrees in America and Germany. Engineering science is playing a very important part in many branches of human activities contributing to the progress and prosperity of all the great nations of the world. The Engineers are now the torch-bearers of civilisation, and without their assistance all progress will come to a standstill.

Gentlemen, I have recently been reading the Royal Charter conferred on this Institution by His Majesty the King Emperor. The first item under "objects and purposes" as described therein is to "promote and advance the science, practice and business of Engineering in all its branches". The other items which follow are the means to achieve the above object. It is time for us to think seriously to what extent we have fulfilled or attempted to fulfil the ends for which this Institution has been brought into existence. I hope, Gentlemen, you will agree with me when I say that the justification for the existence of the Institution and its activities must ultimately be judged by the contribution from the Engineering point of view which we make both directly and indirectly towards the welfare of the country in which we live whether temporarily or permanently. It is very necessary for us to bear this important point in mind and to endeavour at all times to promote this end by all means within our power.

Gentlemen, though it is a platitude to mention that India is a vast country full of natural resources, it is nevertheless a patent fact that the development of the country from the Engineering point of view has been comparatively slow. There are multifarious reasons for this which it is not my intention to dilate on, but I would like to mention that the Engineer must do his bit now and that with all the earnestness that he is capable of. I do not for a moment undervalue the great part played by them in the past which has contributed to the material prosperity of this country, but the work still waiting to be done is very extensive indeed, and we must equip ourselves for the task ahead without undue delay. The Engineers have silently performed their onerous duties in the past, but things have changed now and it is necessary for the welfare of the profession and for the progress of the country that there should be better publicity, the Engineer's knowledge must be widely diffused so that the people may in general, have a better idea of their usefulness and may be inclined to take full advantage of the facilities offered by them to improve the material prosperity of the country.

Gentlemen, I hope, you will excuse me for indulging in these general remarks. Many of you, I am sure, have been feeling in the same way as I have done. I do not intend to bore you with a lengthy address, but I shall only refer to some

Engineering matters to which in my opinion the attention of the members of this Institution should be specially drawn. Some of these points are specially important for the province of Bengal.

Gentlemen, as I belong, by profession, to that branch of Electrical Engineering which is known as Electrical Communication Engineering and as I was during the course of my service under the Government of India more intimately concerned with the development of that branch of Engineering in the country, I would first like to make a few remarks on that branch. We have, in recent years, been able to introduce some of the most modern systems of electrical communication in India, but considering the vastness of the country, we are yet at the threshold of expansion. There are immense possibilities of development of Electrical Communication in India. But this development is dependant on the general uplift of the economic condition of the people. This branch of Engineering is very closely linked with the industrial progress of the country. As big scale industries come into being in larger numbers, there will be an incessant demand for the facility offered by Electrical Communication. We have so far got several important cities linked up by long-distance telephone circuits. Multi-channel carrier Têlegraph and Telephone equipments have been installed on almost all the important routes. Telephone speech is now practicable over routes several thousand miles in length. A single pair of wires transmits a number of messages at the same time between distant places by utilising the carrier principle. Very substantial progress has in fact been made during recent years towards increasing the facilities for long distance communication in India. It should however be noted that we are almost entirely dependent for the above progress on the inventions, research and experimental works carried out in countries outside India. In the earlier stages of dvelopment it is inevitable that this should be so. It is however essential that serious attempts should be made now to develop our own technique of the different Electrical Communication systems. This will lead to great economy and improved efficiency. In this respect the greatest assistance can be rendered by the Indian Universities. I understand that a beginning has been made by the Calcutta University and a Department of Electrical Communication

has been attached to the Science College. This is good as far as it goes, but the problem requires the co-ordinated efforts of the Universities, the Government and the Practical Engineers who are engaged in the installation and maintenance of these systems. The Institution of Engineers can also render substantial assistance by encouraging research and experimental work in this very important branch of Engineering. I fully admit that the task is beset with many difficulties but it is not impossible to overcome them if there is co-ordination between the different agencies which can help.

I would like to give you a few examples to illustrate what I have said above. Take for example the cases of local and long distance telephone systems of India. Hitherto Government have adopted whatever systems they found most suitable for the needs of the country. The apparatus and the fittings are obtained from Europe and America. Very often they have to be altered or specially manufactured to suit local conditions prevalent in India. This naturally means extra expense to the State. Now many of these apparatus can be advantageously manufactured in the country after proper experimental and research work. I do not know of any organisation or institution which has seriously taken up this matter. I know of only one organisation *viz.* the Government Telegraph Workshops in Calcutta where an attempt has been made to manufacture at least a small portion of the apparatus required. I have for many years closely watched the activities of these workshops and the capabilities of the Engineers and the workmen employed therein and I am convinced that with proper equipments and adequate training it is quite possible to manufacture many of the apparatus required for the local and long distance telephone systems of the country. There should however be an organisation for research and experimental work which should operate in close co-operation with all manufacturing firms. To this latter point I would most earnestly draw the attention of all Engineers. Similar remarks apply to other branches of Electrical Communication Engineering, such as high speed telegraph and radio communication system. Another branch of Electrical Communication Engineering in which Indian enterprise has so far made no impression is the Railway signalling system. Block signalling apparatus, to quote an example, of which a large number is required by the Indian

Railways are all imported from outside India. I do not see why the Engineers here should not be able to design and perfect these apparatus for use in the Indian Railways. I have mentioned these facts to draw the attention of the Engineers to the great possibilities of exploring these new fields of activities, which will give extended scope to their Engineering abilities with advantage to themselves and the country in general. I quite realise that for the satisfactory solution of these problems, material resources and industrial organisation are necessary. I hope this will not be wanting if the Engineers, the Government and the Universities make a start and work in co-ordination for preparing and laying the necessary foundation on which the superstructure is to rest. This Institution of which one of the avowed objects is the encouragement of research and experimental work ought to take an important part in the above endeavour.

There are other spheres in the domains of electrical and mechanical Engineering to which Engineers in this country should direct their special attention. They should act in this matter as pioneers. They should, in fact, stimulate public interest and help in the creation of their own fields of work. The Engineers in this country are not unfortunately in the advantageous position of finding ready made fields of activities in which they can exercise their skill and ability as trained Engineers.

In the sphere of Mechanical Engineering the manufacture of machinery and tools is an important item of work, which is now in an elementary state of development. With proper organisation it ought not to be difficult to undertake the manufacture of machinery of all descriptions and sundry other appliances required for the industrial development of the country. The same remarks apply to Electrical Machinery and their adjuncts such as Dynamos, Alternators, Transformers and Measuring Instruments of different types. The Engineers in their individual capacities, and this institution as representing them collectively, ought to play their part towards the attainment of this important object by an extensive dissemination of engineering knowledge and its practical application. It is they who should help in the creation of these new enterprises, in which they will be able to employ their engineering skill with advantage to themselves and for the good of their country.

Before I finish this address I would like to mention one or two Engineering problems which are particularly important for the province of Bengal. I think it needs no apology to mention the recent devastating flood which has caused serious damage to the province and untold suffering to the people inhabiting a large tract of it. The Irrigation Engineers of Bengal have an important duty and responsibility in the matter. It is up to them to devise means to mitigate the effects of flood in Bengal. It will be hardly right to say that it is Nature's Visitation and does not call for serious action as it cannot be prevented, and what cannot be cured must be endured. I do not think people will accept this philosophy. This problem ought to be tackled in the same way as has been and is being done in America and other countries. In this connection the need of research work in Bengal in which both Engineers and Physicists should take part and should work in close co-operation with one another is being strongly felt. There is reason to believe that this has been realised by the authorities concerned and it is hoped early action will be taken in the matter. With necessary hydraulic experiments and proper planning it ought to be possible to do a good deal to minimise the trouble. By the construction of channels, outlets, reservoirs, etc., the vast energy represented by the flow of this huge quantity of water can perhaps be partially controlled and regulated. There ought to be some efficient methods devised for the utilisation of the water for the improvement of the soil of several districts of Bengal, of which the productive power has deteriorated. Not being an irrigation engineer I refrain from going into details. I shall leave the matter for the consideration of those capable of dealing with it from the technical point of view. My object was to draw the serious attention of the members of this Institution to this important matter as the subject is of absorbing interest both from the engineering and the humanitarian point of view.

The next point to which I would draw your attention is the lack of proper electric power supplies in this province. It is true that isolated installations are now being brought into existence in some district towns, but the prospect of obtaining a supply of cheap electric power both for domestic and industrial purposes is far from being realised. I do not know if any efforts are being made for planning a comprehensive

scheme for the whole province, but it is only proper that the members of this Institution who are in a position to do so, should take interest in the subject and by writing technical papers and by appropriate discussions and discourses should help in bringing the matter prominently to the notice of the government and the general public.

Gentlemen, I thank you once again for the great honour you have done me by appointing me the Chairman of this Centre for the ensuing year and for the patience with which you have listened to this address.

Address delivered by Mr. T. R. Sneyd Kynnersley, O.B.E., M.C. at the Seventeenth Annual General Meeting of the Bombay Centre held at Bombay on the 10th December, 1938.

Gentlemen,

I should like to express my thanks to the Members of the Committee for electing me as the Chairman of this Centre for the ensuing year.

Before reading my short paper on Roads I propose to bring to your notice one or two points in connection with the Institution.

At the Eleventh Annual General Meeting of the North-West India Centre held at New Delhi in February this year, Mr. B. R. Kagal, the Chairman, made some very interesting suggestions which you will see in Volume XVIII of the 1938 Journal. He suggests the desirability of a Committee, at Head Quarters additional to the existing ones, called an Education Committee. It would act in liason between the professions as represented by our Institution and the Universities and other teaching and training bodies. To use Mr. Kagal's own words "it is universally recognised that the standard of a profession in any country is the standard of the Institutions in which the professions are taught both in theory and practice. Universities and Workshops of any country are the nurseries where its future engineers are trained".

Mr. Kagal makes the interesting suggestion that a couple of energetic members in each Centre should work for this Committee and co-ordinate the work of the branch with the educational Institutions in the Province so that a Central Committee would have facts and data to work on which would be of the greatest possible service to the profession as a whole.

No engineer is any good now-a-days unless he keeps up-to-date, neither is an Engineering College doing its job properly if it fails to educate its students on the most modern principles, using new data as it comes through from other parts of the world.

It is suggested that our Universities have not yet acquired a sufficiently urban bias and I do feel that the development of the great cities of India is being somewhat neglected by the Engineers of to-day, and more especially such subjects as town planning.

Complaints are made from time to time that young engineer will not contribute papers but I feel that this is largely due to the impression that papers must necessarily be on one of the more scientific aspects of engineering. This is a mistake as there are many subjects of great interest both to engineers and the public which can with advantage be studied by the engineer and form the subject matter of papers. I refer to such subjects as town planning, housing, traffic islands and other safety measures such as subways, foot-bridges, foreshore protection, noise abatement and so on.

At the risk of repeating what you may have heard many times I propose to give you a brief sketch of the road situation in India, as it appears to-day. As President of the Bombay Engineering Congress in 1930 I called attention to Sir Henry Maybury's lecture delivered before the Institution of Civil Engineers in London in May 1929 and reminded members of the fact that our methods of approach to the problems of roads in India were very different to those of Great Britain. Also that in this country very little desire was shown regarding improvements to roads. I mention this to show you how times have changed, for now that 8 years have elapsed it is correct to say thet there is a very genuine desire on the part of the majority of thinking people for better roads in this country. This is something to the good.

Roads have been called "A measure of civilization" and historians have gauged the kind of civilization of nations long gone by, in part, by the kind and extent of the roads they built. Throughout the ages roads have recorded the lives, the ideals, the ability and the strength of nations.

Roman roads in Europe are to-day synonymous with Roman domination. America's prosperity followed her vast system of road construction.

In this connection Democracies do not appear in a favourable light when compared with Dictatorships. There seems to be too many committees and too much talk.

Let us look for a moment at some of the advantages of building good roads :

Firstly. There is a reduction of unemployment through actual construction and due to increased orders to suppliers of materials, machinery and so on.

Secondly. Good roads mean cheap roads and by cheap I mean low in maintenance cost. The cost of a road can only be measured in terms of many years of service. The most expensive road is often the cheapest road to make but the maintenance costs go on year after year and no one seems to mind, mainly because they don't know.

Thirdly. There is a stimulus to the motor trade which deals in private and industrial vehicles to say nothing of the many subsidiary trades employed in the running of motor transport, tyres, accessories and so forth.

Fourthly. The inestimable advantage to trade in general through the ability to move goods from town to town, from village to village and from door to door with the maximum ease and economy. India is proverbially a poor country and it can never be a rich one until every village and every township is connected to its neighbours by a road which is open to traffic all the year round.

We, who live in big cities, scarcely realise the dreadful condition of 9/10ths of this country and how the monsoon rains turn vast areas into lakes or swamps and thousands of villages are cut off for want of road communication.

Until less than a century ago roads could claim to have held a position of primary importance in the country's system of communications and it was due to the advent of railways that they were relegated to a place of secondary importance.

A revival in the importance of road communications has been brought about as a result of the development in recent years of the fast-moving motor vehicle and the demand for better class roads.

The old type of waterbound macadam, moorum and laterite roads built to accommodate the slow moving animal drawn vehicle are no longer suitable for carrying the two types of traffic they now have to carry and are no match for the high speed vehicles in use to-day. In an agricultural country like India where the bulk of produce is carried by draught animals and old fashioned carts with distorted wheels, an enormous amount of damage is done to road surfaces by these wheels with their rough iron tyres and the damage is made permanent by pneumatic tyres sucking up the disintegrated surface which is scattered to the four winds of heaven. In this way we get a series of potholes which are filled with water during the rains and turned by subsequent traffic into a quagmire.

And now we come to the real crux of the trouble, money, or the lack of it. Most people admit that it pays to build a road properly to start with and save maintenance charges later. The trouble is to get the money to make it with. Many Government Officers have admitted to me that they would build better roads if only they could get the money but when one suggests raising a road loan they invariably say that the Finance department will not hear of such a thing. Some commercial concerns have even offered to build roads on a kind of hire purchase system, but Government still say it is impossible because the offer is a loan in disguise. How many more years are to pass and how many more crores of public money are to be wasted before some one big enough will deliver us from this apparently hopeless situation. We have engineers who are able and ready to make good roads. We have senior officers of Government who say they want to make good roads. All materials are available in this country, the ability is here and even the money if only it can be made available.

It is often argued that the railways are the stumbling block. So much public money and Government money is invested in these Railways that Government are said to be unwilling to allow good roads for fear of competition.

If this is true we must be working under a transport monopoly and why should the progress of the country be stifled in this way.

If it is not true then let the Railway authorities combine with the road makers and let us have a system of communications which will do credit to all concerned. If good roads are made and thousands of villages linked together there is no shadow of doubt that the trade of the country would be improved to such an extent that railways in common with everyone else would benefit; and the revenues of the Central Government would go up in due proportion.

I would like to draw your attention to an extract from the road report published by Messrs. Mitchell & Kirkness in 1933 under the heading of *Road Finance.* "It is urged that just as Railways have been developed by the necessary capital being provided in advance, other transport systems should be assisted in a similar manner and as the situation regarding road development calls for urgent attention, it is suggested that provision should be made for its finance by the issue of Road Bonds or by a Road Loan.

Road development is essential and is urgently needed if motor transport is to fulfil its object with the greatest economic advantage to the country, but funds are lacking at present and as a consequence instead of our road communications being improved to accommodate modern road transport as feeders to our railways, they are falling into a state of disrepair. Paucity of revenue, however, is not a justifiable reason for the failure of our Governments to develop our roads, there are other means of finding the money when necessity demands, such as have been adopted with great success in other more advanced countries and that is capitalising some of the current revenues for the payment of interest and sinking fund on a Road Loan or Road Bonds".

That was over 5 years ago and still the roads with one or two brilliant exceptions are as bad or worse than ever.

You may think that the broad question of finance has little to do with us as engineers but engineers and financial experts must work together in a matter of this kind and even then they can do little without public backing. It is necessary for us to keep up-to-date in the latest methods of making good roads but we also have a duty in designing these to avoid as far as possible the appalling number of accidents whch are taking place to-day and the right planning of roads is almost as important as the right building of them. You will all remember the stir that the Bhita train disaster caused and the exhaustive enquiry which was carried out under Sir John Thom, the Chief Justice of the Allahabad High Court.

Those responsible for our highways could learn much from this for the tragedy of Bhita is being repeated on our Indian Roads month after month, year after year, yet in how many cases is there any real investigation of the cause and how often is anyone except possibly those suffering in the accident held to blame.

Badly designed roads are responsible for two great restrictions upon the expansion of motor transport. They limit speed by congestion and dangerous conditions and legal restrictions have to be put in force to prevent accidents and so on.

The other main trouble to be avoided is known as "ribbon development", the building of dwelling houses, shops etc. as a fringe along roads which carry the bulk of traffic one house deep on both sides of the highway. The frontages of these houses and shops are as a rule far too close to the road and they cause obstruction through the parking of cars and lorries at the sides. All well designed through roads should be completely free from this parking trouble, service roads being built at the back of the houses to take the local traffic. If money is not forthcoming for service roads the houses should be set back sufficiently far to allow parking accommodation away from the road itself.

In this country we still have a chance of protecting the roads from ribbon development but if plans are not laid properly and in good time a road system will gradually grow up with

all the faults which the people in Europe know so well and in the words of Mr. E. H. Fryer, Deputy Secretary of the Automobile Association of Great Britain:

"Land must be sterilised from building development well in advance and when the road is made all building must be kept away from the frontage.

In visualising the road of the future, ample width should be allowed for at least two separate carriage-ways.

As pedestrian footpaths and cycle tracks will have to be allowed for an ample overall reservation should be insisted on at the start.

A cross road on a modern road is an anachronism. No road junction should be so designed as to slow up the through traffic stream. A series of filterways which merge traffic into the main stream need to be provided and fly-overs to prevent the interruption of the route by cross-roads."

I have said enough I think to give you something to think about and I sincerely hope that engineers will gradually come to look on roads as of first class importance and realise that they are one of the most vital things which make for a country's prosperity.

Address delivered by Mr. Mohsin Ali, I.S.E., at the Eighteenth Annual General Meeting of the United Provinces Centre held at Benares on the 12th January 1939.

Gentlemen,

I cannot thank you sufficiently for the honour you have done me by electing me as your Chairman for the ensuing year. I am certain you could easily have found another member more highly qualified than myself to occupy this position. But, if a consuming desire to see our Institution as ranking amongst the most progressive engineering societies of the world, and to work for it whole-heartedly, be a qualification for its provincial Chairman, I can claim to possess it in ample measure. During the couple of years that you thought fit to entrust the duties of Secretaryship to me, I got so interested in the welfare of the United

Provinces Centre that, though fully conscious of my unworthiness to be its Chairman, it is a matter of real pleasure to me to be able to continue my intimate connection with it and to be allowed to take an active part in its day-to-day working.

Backward India.

The practice of engineering is as old as mankind, but its highest developments have taken place during the last century, as a result of the discovery of certain physical laws and the expansion of the mechanical sciences. This progress has gathered momentum with the flight of time, but it is sad to reflect that it is not marching as fast in India as in the other countries of the world.

Last year I had the opportunity of making a hurried trip round the world, and so obtaining a cross-sectional view of some of the more advanced countries, and those, who have had a similar experience, will bear me out when I say that India is, by comparison, very much behind in adopting the latest and the most modern methods of engineering practice and construction. I would like to place before you this morning my views as to how it is possible to accelerate this process in India.

Conference of Ministers of Industries.

The so-called mechanical and electrical sciences, and their practical application to the every-day needs of man, were developed by the inhabitants of Western Europe, and it is only natural that there should be a certain amount of time-lag in engineering developments in the eastern countries, but that does not explain India's backwardness entirely. Other Asiatic countries, notably Japan, and more recently, Turkey, are advancing very rapidly, and there is no reason why we should not do the same. It is, however, a matter of satisfaction that the new autonomous Governments in this country are alive to this necessity. The recent conference of the Provincial Ministers of Industries at Bombay have taken note of the urgency of adopting measures for an all-round industrial development, and we can look forward to tangible results in the not very distant future.

Provision of Engineering Education in Universities.

Any scheme of industrial or engineering development must be broad-based on a sound system of technical education. Most of the few existing engineering colleges in India were

established by the British Government with the object of training young engineers for recruitment to their various public works departments. These institutions, of which the Thomason College at Roorkee was the premier one, served their purpose very well, but the development of a semi-continent like India cannot depend on the circumscribed activities of Government public works departments, nor can it be financed adequately from Government revenues or funds. For a continent-wide development, a big army of engineers of all descriptions—civil engineers, mechanical engineers, electrical engineers, agricultural engineers, municipal engineers, mining engineers, marine engineers and a host of other engineers—are required. This want cannot be supplied by a college here or a school there. The rudiments of engineering practice have to be inculcated in the whole body of the rising generation in primary and secondary schools in order to make them engineering-minded, followed by ample provision for the training of engineers in the universities, every one of which ought to have a faculty of engineering for supplying the demands of a continental programme. There is no university in the world, except some of those in India, which has not its faculty of engineering. The pure sciences are taught there chiefly as a preliminary to the study of engineering, agriculture, technology or medicine. Of course a certain number of students at all universities are whole-time devotees at the shrine of pure science, but 90% of those who study it do so because it forms part of their technical or professional education. This is not so in an Indian University (I am referring to the older universities) where students flock to the pure science classes, because no provision exists within its precincts for the teaching of engineering, or technology. I must here mention an honourable exception, *viz.* the university where we are gathered to-day. The first building to be put up at the newly projected Benares Hindu University was the Engineering College, which has since been sending out an ever-increasing army of engineers, now filling responsible positions as leaders of industry in every corner of India.

Apart from the technical side of their education, it is essential to develop in all budding engineers certain qualities of leadership to fit them for their life's work. These qualities are better cultivated in the larger and freer atmosphere of a university

than in the cramped space of an isolated college or school. The corporate life of the university furnishes innumerable opportunities of contact with men and women of all shades of opinion, with men and women of learning and distinction, and with young men and women destined to be the future leaders in all walks of public life. The participation in the debates of the University Union and in the proceedings of learned and scientific societies develops a broad outlook, an early consciousness of the country's problems, and good powers of expression, all of which are essential qualifications for future leadership. It is sad to think that the majority of our future leaders in the field of engineering are deprived of this wonderful opportunity, which, so far as they are concerned, is going to waste.

Unemployment.

It is a fashion in engineering circles these days to complain of the unemployment of young engineers. I am afraid I am out of sympathy with this pernicious view. What young engineers complain of really is not a lack of opening, but a comparative shortage of comfortable Government posts where they can just slip into a groove, and remain in it for the rest of their life, drawing yearly increments automatically with the revolutions of the earth round the sun. With the lapse of time, they sink deeper and deeper into their respective grooves, and can only be jerked out of them by some superhuman effort. No. I am emphatically of the opinion that we have too few engineers, and that the first thing we want for our continental needs is a large and ever-increasing army of them. We want, in other words, a new orientation of educational policy generally, and a universal extension of engineering education through the universities.

The Wardha Scheme.

I am glad to say that our new Provincial Governments are alive to the need of the former, and it is to be hoped that the Wardha Scheme, which, at present, is in an amorphous state, will crystallize into a living organism capable of producing young men and women imbued with enthusiasm for practical work, with a bias in favour of manual labour as against literary dilettantism. While the Wardha Scheme, if properly worked, will produce a continuous army of active men and women, it is necessary that the universities should keep pace with this development, in order to provide leaders in the field of engineering and industry.

Finance—A lesson from America.

Another matter requiring serious consideration, when undertaking the development of a sub-continent like India, is the question of finance. Money is said to be the sinews of war. Much more so is it the sinews of development, and the difference between the success and the failure of any scheme of development is the difference between sound and unsound finance. I will illustrate this by an example. Some of the largest feats of engineering that I have seen are the two bridges which span the Bay of San Francisco, the Oakland Bay Bridge and the Golden Gate Bridge. The former is about 7 miles long—the longest in the world—and has several spans. The latter is 9,000 feet long, has a middle suspension span of 4,200 feet, also the largest in the world, with towers 746 feet high, and a clearance of 220 feet between the deck and the water surface, sufficient to allow of the largest ship in the world passing through. Other notable features of this great engineering work are : (1) the bridge is 90 feet wide, with a 60 feet roadway between kerbs and 10 feet side-walks for pedestrians, (2) the foundations go down 110 feet below mean water surface, (3) 10½ million cft. of concrete and 83,000 tons of steel were used in its construction, and (4) the cable is 36½″ in diameter. But the chief things to note about these bridges are : (i) that they are neither constructed nor financed by Government, and (ii) that they are self-liquidating. The cost of the Golden Gate Bridge is 35 billion dollars, which, at the present rate of exchange, is about Rs. 9,35,00,000/-, not much less than the cost of the construction of New Delhi. The corporations responsible for the construction and maintenance of the bridges were constituted by legislative sanction. The money was raised by floating bonds, and a toll is levied on all traffic passing over the bridges. The amount of the toll has been so designed, that, after paying the charges on account of interest, depreciation and maintenance, the capital will be repaid in 35 years. It was objected by pessimists, when the projects were first mooted, that such methods of finance would restrict traffic. As a matter of fact, the traffic has developed much more rapidly than anticipated, and two years working of the Bay Bridge and one of the Gate Bridge have proved that the projects will liquidate their capital in a shorter period than originally allowed for.

When the whole of the capital has been repaid, it is proposed to reduce the toll by 50%, and to contribute the savings, after paying maintenance and other charges, towards a fund for the construction of similar works of public utility.

The Self-Liquidating Method.

I may add that this self-liquidating, or the "pay as you go" method of finance, as it is locally called, is not limited to these two bridges of San Francisco, but applies to many of the large public works undertaken in America in recent times. I quote below from the Engineering News Record of February 17, 1938—"Construction on a self-liquidating basis of ten super-highways, three of them crossing the country from east to west, and seven from north to south, is proposed in a number of bills now before the Congress." The total cost of these is estimated to be six billion dollars or about 16 arabs of rupees. These bills provide for the creation of a U. S. Highways Corporation with authority to issue bonds which will mature in 60 years, and bear interest rates not greater than 3%. The bonds will be repaid by toll charges on the proposed roads. The highways will have a right of way of at least 300 feet wide, and contain from 4 to 12 lanes, depending on traffic conditions. The roads would be required to have central dividing strips, to eliminate all grade crossings with other highways, and to separate passenger vehicles from trucks.

I may add that this method of finance is not confined to engineering works only, but a number of State and Municipal Governments of U. S. A. are run on this policy, known locally as "grasshopper thrift". This has given such good results that other States are falling into line. Nor is this self-liquidating principle the monopoly of America. The new highways of Germany and Italy have been similarly financed. Much nearer home, and in our own times, the Irrigation Branch of these Provinces built a few small bridges for the District Board of Meerut, who financed the projects as self-liquidating units.

"The old man of the sea."

When you come to look at this method of financing you find that it is as simple as the air and as old as the heavens, and you wonder why it has not found favour with the orthodox

school of economists. When a man builds a house for himself he does not usually borrow the money for it, and then keep paying interest all his life unto the *n*th generation. If he has to borrow some of it, he tries to pay it off as soon as possible from his revenue or income, so that, in a number of years, the house is his own inalienable property. What holds good for private finance must be good for public finance, and it cannot be right to bequeath to your children and your children's children a load of debt and interest charges which they must go on paying for ever and ever. Raise capital for immediate needs of development but pay it off from revenues. Let the tenure on your shoulders of the "old man of the sea" be as brief as possible. We have the example of Iran, building out of its revenues, its first arterial railway, 865 miles long and crossing some of the most difficult mountainous and desert country in the world at a cost of £30,000,000 or nearly 40 crores of rupees. We have the example of Hyderabad acquiring its railway lines out of its revenues. The thing is not impossible and can be done.

The Example of Turkey.

The marvellous recovery of Turkey after the Great War was due, in large measure, to the foresight of modern Turkish builders, who financed most of their projects of public improvement out of their revenues. I quote below from the *Times* Special Turkish Number of August 9, 1938—"It is well to know that the heavy programme of railway construction and industrial development has been financed directly out of revenue or on short-term credits, and only to a minor degree by internal loans. State productive capital investment of all kinds ranged from £T. 27,000,000 in 1931-32 to £T. 45,000,000 in 1936-37, with a total in that period of £T. 209,000,000 of which some £T. 55,000,000 was provided by loans. An important result is that the railway administration is not burdened with interest and renewal charges on a large part of the 1,780 miles of railways constructed since the War, so that the railway budget has no difficulty in meeting the annuities payable on account of the pre-war railway lines which had been expropriated by the Government, a state of affairs which may well be envied in many countries."

Irrigation Retrenchment Committee, U. P.

As you know, our own Government is trying to explore ways and means of retrenching expenditure in the Irrigation Branch, and a committee is sitting at the present moment with that express object in view. The main item of expenditure is on account of interest charges which amount to Rs. 1,07,00,000. This they cannot touch unless they repudiate the debt, which is an unthinkable proposition. But if the older irrigation works *viz.* the two Ganges and the two Jumna Canals—highly productive schemes—had been financed on a self-liquidating basis, we should have paid off the capital long ago, and the interest charges on our budget would have been less at the present moment by Rs. 33,33,000/-.

Communications.

I have dealt above on the need for more widespread facilities for technical education and for a more rational method of financing schemes of public utility. I now come to my third and last point, *viz.* the very urgent need for improved communications in order to accelerate development in this country. In the earlier part of my address I referred to the backwardness of India in respect of engineering practice, but I must qualify that statement as regards irrigation. During the last century, India has developed an irrigation system such as exists nowhere else in the world. In this respect we can give points even to America and Egypt. Unfortunately, communications have not kept pace with the development of agriculture which came in the wake of irrigation. When you build a canal in any country, you should also see that the resulting increase in produce has commensurate facilities for a quick outlet to the markets of the world. This has not taken place in India. Railway lines have no doubt been built, but road development has lagged very far behind. Mr. H. C. Smith, O.B.E., in his highly informative article on Road Communications in India, in the Supplement to the *Statesman* of October 26, 1938, has given several reasons for this backwardness, the most important of which is that, unlike canals, roads pay no dividends on the capital invested. One method of remedying this has been indicated above, namely, levy tolls and pay off the capital in a number of years, as in the case of the self-liquidating road projects of America, Germany and Italy.

The Central Road Fund.

The Government of India have found a partial solution by building up the Central Road Fund from direct taxation. It is evident from the facts and figures given by Mr. Smith that the fund cannot provide all the money for the necessary road development. I quote below from his article—"The Government of the United Provinces commenced a five-year road programme in 1935-36, a portion of which is to be financed from loans. Of the total cost of Rs. 107 lakhs, roughly Rs. 11 lakhs is to be met by grants from the reserve in the Road Development Fund, and Rs. 55 lakhs from the U. P. Government's share of that fund. The balance of Rs. 41 lakhs is to be borrowed by Government and to be repaid with interest from the future income of the Province from the Central Road Fund".

Similarly the Central Provinces have a programme of 27 lakhs apart from that financed from their share of the Road Fund, and Madras is preparing a scheme costing Rs. 3 to 3½ crores to be financed to a large extent from a loan. I quote again from Mr. Smith's article—"Bombay has to its credit the largest programme so far adopted by a Provincial Government. A seven-year programme which it is intended to commence next year has been drawn up, involving an expenditure of roughly 4 crores of rupees. In this programme, schemes amounting to Rs. 175 lakhs are to be financed from the Presidency's share of the Central Road Development Fund and the balance from loans, supplemented to some extent by the Provincial Road Fund derived from surplus revenue from motor vehicle taxation consequent on the introduction of a Provincial motor vehicles tax." It will be seen that the Road Fund is not anything like enough for the immediate needs of road development. Money must be raised, and it is to be hoped that the various Provincial Governments will seriously consider the advisability of raising short term loans and paying them off as quickly as possible out of tolls, in preference to swelling the debt and interest charges for all time to come or to keep drawing on their future income from the Central Road Fund, which should be earmarked for future developments.

I would like to refer once more to what Turkey is doing in this regard. The total mileage of roads bequeathed by the old regime was 4,660 miles. Since 1923, their successors have built 6,000 miles out of revenues, and at the present

moment 9,000 miles are under construction and 5,000 more miles projected. Very soon the country will have 25,000 miles of roads. I quote again from the *Times* Supplement—"The new policy aims at providing the country with a close network of roads between every Turkish town or port—a network which, superimposed on the railways, will reach every frontier and change the whole economic face of this part of the Near East." We too have a similar road ideal, but we must also create the conditions for its realization *viz.* sound finance and ample qualified staff.

I must apologize for having inflicted upon you an address which is longer than is usual on such occasions, but I set to myself the task of developing the thesis "how to accelerate the progress of engineering development in our country," and I do not think it would have been possible to do so in a shorter space. In fact, a lot more could have been said on the subject, but I confined myself to 3 main issues, *viz.* (1) a more wide-spread system of engineering education, both "horizontally and vertically", if I may so put it, (2) a radical change in our ideas of finance, and (3) an immediate improvement and expansion of means of communication. You will no doubt agree that good and ample communications are a *sine qua non* for the development of a country, but I feel somewhat doubtful as to whether I have succeeded in convincing you with regard to the other two propositions. In any case, I was in duty bound to place my views before you, and, if I have set you thinking on these controversial subjects, I shall feel that I have fulfilled my duty as your Chairman. I will only add, in the words of that great liberal thinker, Lord Morley, "The modern emancipation will profit us very little, if the *status quo* is to be fastened round our necks with the despotic authority of a heavenly dispensation."

Once more, I thank you for the honour of being your Chairman.

Address delivered by Mr. N. Sarabhoja, L.C.E., at the Fourth Annual General Meeting of the Mysore Centre held at Bangalore on the 10th December, 1938.

Gentlemen,

I am deeply thankful to you all for having elected me as Chairman of the Mysore Centre of the Institution of Engineers (India) for the coming year. Indeed, you have done me a great honour by asking me to shoulder the responsibility of this Centre. I accepted the Chairmanship as in duty bound, but not without diffidence and hesitation; because there are more abler members of this Centre upon whom the choice could have fallen and who could have more suitably occupied the Chair. I shall, however, endeavour to do my best with your co-operation. Before proceeding further, I wish to thank on behalf of this Centre, our retiring Chairman Mr. Y. K. Ramachandra Rao, whose activities on the Committee are well known and I need not repeat them here.

I do not wish to make a long speech detailing the several Engineering activities and achievements in the State, nor is this the occasion for me to do so. I, however, wish to make a few practical suggestions in our daily activities. It is the knowledge that we acquire in our works that counts as a great asset. Every Engineer must be proud of his achievement and in a way feel bound to look to the advancement of the rural parts of the country, for, 80% or more of the people in India live in villages of less than 5,000 population.

We, Engineers often face with great difficulties—it may be works of magnitude or works of trivial nature—and they are overcome by practical application of the mind. But the solution obtained and the knowledge acquired are not given wide publicity. It may be the proud privilege of one man to solve the problem. In the interest of the Engineering profession, it should be the duty of every Engineer to record his experience and give it to others. I feel knowledge should not be a sealed book in one's memory. I would appeal to every Engineer to inculcate in him the power of observation, and the habit of committing to writing whatever knowledge he gains in his field of activities, however imperfect it may be.

Another point which strikes me is that we are not writing any paper for the journal of the Institution. We have works of magnitude and our Engineers are well equipped and have large scope for writing technical papers. What is required is merely to reduce their day-to-day experience to writing. I take this opportunity of making a special appeal particularly to our young Engineers to make it a point to write one article at least once a quarter, and make this Centre take its proper place in the Institution of Engineers (India).

One of the vital problems of the day is the improvement of village communications and drinking water supply in rural areas. Everywhere the cry for good village roads, bridges for *hallas*, and wells for drinking water, has been universal, and it has not been possible to achieve much in this direction on account of paucity of funds and large areas to cover. We all know and hear every day of philanthropic gentlemen coming forward with donations for constructing works of public utility like a school building, a maternity hospital, or a veterinary hospital or a temple etc., and if we could induce such gentlemen also to contribute freely for constructing a bridge or creating an approach road to villages in rural areas, or digging a well, it will really be helping a good cause and would go a long way in solving the problem of village communications and drinking water supply. The work to be done in this direction is so vast that a certain amount of public sympathy has to be enlisted in addition to Government help for achieving good results.

There is another problem, which is perhaps peculiar to Mysore, and which is a subject of engrossing interest at the present moment. I mean the problem of financing public works. Engineers in their role of duties are often subjected to criticism for reasons beyond their control for any delay in the execution of a work and many a time they have to work under unwholesome circumstances. There are certain classes of public works which are under the joint purview of different bodies like Government, District Boards, Municipalities and Industrial Concerns, and require to be financed proportionately by them. A scheme would have been technically sanctioned but the actual execution will be delayed for want of allotment of funds from several bodies, however urgent and useful the work may be. In order to overcome such difficulties and to

ensure speedy execution of works of public utility, I would suggest the constitution of a central fund known as "development fund", under which all works of public utility may be classified and executed. Such a procedure will, I believe; hasten the timely realisation of many of our public improvement schemes and early confirment on the people the benefits resulting from such schemes.

In Mysore the restoration of Minor Tanks forms a very important item of work requiring large amount of funds. Here again, delays are caused due to want of consent of the *ryots* to pay contribution, and even if they agree, there may be delay in the collection of money. It is a matter of real hardship for the *ryots* who are already poor to pay before they get any crop. Government set apart a sum every year for restoration of tanks in their annual budget, but the major portion of the grant lapses for want of works to be taken up due to contribution not being paid up. To enable the ryots to pay the contribution, it seems to me to be necessary to allow them to get the benefit of a good crop ; that means the tank should be restored before they are asked to pay. The first investment has to be made by Government. On this principle a far-sighted programme should be drawn up. During the first one or two years the Government may advance the money fully and restore a good number of tanks. The contribution realised under these tanks may be constituted into a fund. The Government in later years may only supplement the same. Proceeding in this manner, I think in the course of 15 to 20 years, it may be possible to restore most of the tanks in the State.

Gentelmen, I do not wish to weary you long. Before concluding, I wish to lay special emphasis on the value of scientific research into irrigation problems. In irrigation matters Mysore has far advanced and we have got to our credit large reservoirs designed and built by men of talent. We have not, however, fulfilled one duty, *viz.* establishing a Research Station in Mysore. Punjab and Bombay have been doing very useful work and a number of pamphlets have been published on the work done so far. Without duplicating the work, I feel there is scope and need in Mysore to have such a

Station, as conditions here are different from other parts of India. A Research Station will, I believe, make a most material contribution towards the solution of several problems of importance and significance applicable to the irrigation works and in the State.

I once again thank you for the honour you have done by electing me as Chairman.

Before I take my seat, I offer my prayer to God Almighty

> "*The Architect and Engineer* of this huge and complicated Universe, who creates it, preserves it, transforms it and is the *Saviour* of its inmates."

Address by Mr. A. C. Flower at the Annual General Meeting of the South India Centre held in Madras on the 24th November, 1938.

Gentlemen,

As announced at this meeting, I shall continue to be the Chairman of this Centre up to the end of March, 1939 when I am due to retire from service in this country. You will then have to elect the Chairman for 1938-39. I must, before proceeding further, thank the Committee Members for having asked me to continue as Chairman for 4 more months. I feel that the only way in which I can show my appreciation of the honour they have done me in this matter is to do my best to discharge the duties of the office to advance the interest of this Centre.

I should like to review briefly the works done by this Centre during the past year. The Annual Report has already been read and you are more or less conversant with the matters recorded in this.

During the year under review there has been an addition of 8 members, of whom 5 are Associate-Members and 3 are Students. 4 members have left the Centre and are no longer attached to us. There were 8 lectures and talks. In most of

these our Engineer Members have contributed their own actual experience and knowledge of the work they executed, and this, I am sure, has benefitted our younger members. I am glad to say that our "Students" also have contributed their share. I would particularly appeal to all our "Students" not to feel diffident or shy but to mix freely with their seniors and take an active part in the proceedings of this Centre as they will, by this means, further their knowledge and develop new ideas in Engineering practice.

I regret I have to refer to the comparatively poor attendance at our meetings. This is specially due to lack of response from the members resident in Madras. I would once again appeal to all of them to take a more active part in increasing the utility of this Centre.

Far-reaching changes, affecting the industrial and economic life of this country, and particularly this Presidency, have taken shape in the last few years. The availability of electric power has given this Presidency an advantage in this connection which has been very ably availed of.

The industrial advancement of the country is largely dependent on its Engineers, *i.e.*, on you so far as South India is concerned. As an Engineer, to be successful it is essential to keep abreast of the times and adopt modern methods evolved out of the latest researches both in the manufacture of materials and in the design and execution of works. Many of you must have seen works which have been simplified in design and construction and reduced in cost by studying the advance made by others and become aware of the difficulties met with by others and how they had been overcome. If you would only give the benefit of your experience to other members of this Centre, you would be rendering a great service to the Engineering profession in this part of the country and justify the existence of this local Centre.

I would, therefore, ask every one of our members to remind himself on this day of his obligation to contribute his share to make this Centre a genuine success.

As for myself, I assure you that, even after I have left this country on my retirement, I shall be keenly interested in your activities and will always be delighted to hear of the increasing prosperity of this Centre.

Address by Dewan Bahadur Amar Nath Nanda at the 12th Annual General Meeting of the North West India Centre held at New Delhi on the 25th February, 1939 :—

Gentlemen,

I have first of all to thank you most heartily for your having elected me unanimously as the Chairman of the N. W. I. Centre of the Institution of Engineers (India) for 1939. In this behalf I am making a confession of my innermost feelings, when I say that the letter of your Honorary Secretary intimating to me your above decision proved a most pleasant surprise not because there was anything amiss in that decision, but because my age-long conviction had received direct proof of the fact that the *esprit de corps* of the Engineering fraternity in this vast country, although not having received so far a systematic and regularized nurture on otherwise a receptive soil, was, nevertheless, a potent factor to reckon with inspite of the fact that territorial re-adjustment had set up a barrier between the Punjab and Delhi, which later prior to the memorable year of 1912 formed an important limb of the land of the five rivers.

While saying this much, I entertain the hope that this kinship will subsist as it exhibits a sturdy link in the endless chain, which the great Institution of Engineers (India) has forged to knit together in fraternal bonds the Engineers of this vast country in mutual help, co-operation and concord to do constructive service to a common motherland.

Engineering is a profession which has done more for the material progress of the world than any other profession. Scientists no doubt discover scientific truths after laborious researches, but it is generally vocation of the Engineer to harness these truths to the services of man. In these decadent times when under the cover of the so-called new ideologies the thumb rule of brute force tramples under its feet the old well established moral values, precepts and standards both in the national and international sphere, the Engineer too is liable to be swept off his feet, nay, is forced to serve as a tool in the manipulation of the newly forged engines of tyranny.

In the golden period of Ram Raj in ancient India the aeroplane was called as *Pushap—Baban* or the flower-laden plane of the Heavens, its proto-type of the present age of *Kalyuga* is the *bomber ;* mark the difference.

In India of all countries, the role of the Engineer is a very important one, as the success of the Engineer will bring in its make real solid and substantial advance in every aspect of the country's life and also promote the development of its material resources. This fact lends dignity and place of honour to the Institution of Engineers (India) which is an all-embracing body as it welcomes to its membership fully qualified Engineers without distinction of nationality, caste and creed. In fact it is a fraternity of art and science, whose watch-word is unity and progress. Membership of the Institution is becoming more and more recognized as the hall-mark of the Engineer in this country and it is my earnest wish, as a member of this profession, to see that our Institution takes its proper place amongst the great technical Institutions of the world. To achieve this end, however, it is necessary amongst other things to set up high standards and traditions and as time rolls on, to insist rigidly on the maintenance of these high standards and traditions.

This brings to the forefront the question of the great importance and utility of the local associations in furthering the fundamental objects of the parent Institution. In fact, as has been said before more than once, every local association, and we have got as many as seven in the whole of India, is the Institution of Engineers (India) in that particular Province or part of India and it is the day-to-day vital life of each local association which would add materially to the life and vigour of the all India Institution.

Our N. W. I. Centre, I understand, was opened in 1926 or 12 years ago and its present membership is 144 which compares favourably with the membership of the other centres as 3 centres are above us and 3 below us.

I have read with great interest the annual addresses of my two esteemed predecessors in office—namely Khan Bahadur A. G. Khan and Mr. B. R. Kagal as reprinted in the journals of the Institution for 1937 and 1938—the Khan Bahadur's address is replete with valuable basic information about the Institution and the local centres and the fundamentals of the functions, aims and objects of each in its respective sphere of

action. The duties and arena of efforts of the student Engineers, who form a major nursery so to say, for the eventual augmentation of the membership of the Institution, have been lucidly set forth, and lastly the Chartered Engineer has been given his rightful place in the framework of the whole picture.

Mr. Kagal has laid emphasis, and quite rightly, on the necessity of the day activities of a local centre and has given in this behalf useful information about the present progressive outlook of the N. W. I. Centre in possessing a local habitation, reading room and library and also in having instituted a system of lectureship on varied Engineering subjects. I most gladly endorse his remarks that any centre could be justly proud of such an achievement. I also find great wisdom and usefulness in his suggestion for a Bureau to collect engineering statistics and other connected information, and an Education committee at the centre which later should prove instrumental in helping to mould and shape the Educational Policy of the different Universities in this vast country in relation to the Engineering profession. Here I wish to emphasize this matter a bit further. Provincial services are gradually taking the place of the all India services with the result that the autonomous Provincial Governments are recruiting Engineers in large number for their cadres. As matters stand at present, the maintenance of communal percentages constitutes one of the chief guiding factors in the recruitment of the candidates to staff the Engineering services. In this behalf, our Institution has an important role to fill, namely, to exercise necessary measure of influence and vigilance in order to ensure that the high standard of Engineering qualification is well maintained. This applies also to the Engineering faculties of some of the Universities, which turn out Civil and Electrical Engineers.

Lastly, I quite agree with Mr. Kagal that there is a great need at the present day of incorporating in the curriculum of our Engineering college course of teaching for the diploma or degree of a Civic or Town Planning Engineer.

As a member of the Lahore Improvement Trust and in this capacity having had to deal with Civil Engineers, who have set up private practice of their own and have amongst other things to prepare layout plans on behalf of their clients, I have felt the want of this qualification in our Civil Engineers.

While calling the N. W. I. Centre as my own, not only by virtue of my having been its member for a number of years, but for the additional reason of my having been elected its Chairman for 1939, I must speak of the Punjab in general and of Lahore in particular not omitting from this brief mention the Punjab Engineering Congress.

This Congress—a semi-official body with a membership of more than 300—was founded in 1912 and has been doing very useful work ever since in building up a valuable store-house of Engineering, chiefly in the field of irrigation.

Prior to the grant of the Royal Charter to the Institution of Engineers (India) efforts had been made more than once in bringing Punjab Engineering Congress within the fold of the Institution. Some of the senior members of the council had even taken the trouble of visiting Lahore in order to expound the advantages of the Congress in the larger interest of India becoming a part of the Institution. But it was chiefly due to the opposition of certain die-hard elements in the Congress and the requisite measure of love and enthusiasm for the Institution not having yet been generated amongst the young Indian Engineers that this matter failed to come to fruition. As I had taken considerable share in the long drawn negotiations, the Congress Council towards the end of 1936 entrusted to me the duty of resuming contact with the Institution with a view, if possible, to arrive at a workable formula of amalgamation. This having been done by me soon brought a reply from the Secretary of the Institution something to the effect that the Institution under the Royal Charter was precluded from making any overtures for amalgamation and that it was for the members of the Punjab Engineering Congress to apply for the opening of a local centre of the Institution at Lahore which would take the place of the Congress. On receipt of this reply the question was dropped for the present by the Congress.

In view of this it is best to let the Punjab Engineering Congress run its own independent course as it is doing at present.

Having, however, said this I must say that we cannot afford to let alone Punjab, which occupies almost a pre-eminent place in the whole of India in point of Engineering achievements. Its magnificent system of canals fed from the great rivers

traversing this land and which have turned vast arid tracts into smiling fields and given rise to flourishing colony towns like Layllpur and Sargodha is the envy of the whole world. The N. W. Railway system is not only a vast net work of railway lines and a great administrative unit for promoting trade and communication, but in its Engineering aspects—such as river training works and bridges etc., it can hold its own against any other system in India. The Mandi Hydro-electric Scheme also not only furnishes a good example of the latest form of Engineering enterprise for promoting industrial development, but opens up a vista of further schemes of this nature by the harnessing of the glacier-fed waters of the great Himalayan range which debauch into the plains at sundry places through deep gorges and whose thunderous roar is almost audible to us in the plains of the Punjab.

I need not labour this point any further, suffice it to say that the Punjab—already indebted to its Engineers for its present development—has need for this fraternity in even larger measure for its further amelioration and advance. In view of this I consider it in the very fitness of things that Lahore as the capital of the Punjab should form a separate local centre of the Institution of Engineers (India) and it is therefore a very wise decision of the Council of the Institution to have fixed the venue of the next annual meeting in Lahore.

Now please note that while advocating the formation of a Local centre in Lahore, I do not by any means wish to be disloyal to the N. W. I. Centre. On the other hand I consider this centre to be an essential one chiefly for two reasons namely :—

One. It is from this centre that we have to carry on our campaign of persuasion and enlightenment amongst a large body of young Engineers of the Punjab who have not yet felt it to be their duty to join the Institution and thereby help to widen the scope of opportunities for good work in the best interest of India which the Institution is in a position to command.

Two. Having cast the horoscope of the Institution in collaboration with a senior member of the profession, our joint reading is that Delhi as the capital of India would eventually form the permanent home of the Institution of Engineers (India) and your local centre is thus the nucleus of that home and as such should command goodwill and support of every engineer.

Lastly a word about the detailed work of this centre during 1939, in this behalf I already feel assured of an abundant measure of loyal support, sympathy and co-operation from the local members, many of whom have given unsparingly their time and interest to this labour of love, while others will, I feel sure, seize the opportunity now afforded of rendering useful and abiding service to our profession through this centre.

IMPACT FOR R. C. BRIDGES

BY

Dr. M. A. KORNI, Member.

A rolling load on a bridge creates an unbroken chain of changes in statical equilibrium and, therefore, the effect on the bridge is dynamical. The dynamical forces cause a further deformation in addition to the statical, due to the weight of the rolling load when at a standstill. The amount of this additional force, called dynamical force, depends on many factors. The first factor is the velocity of the movement of the rolling load which vibrates the bridge. Against this is a negative factor like damping materials with which the bridge is provided. This causes a diminishing effect on the amplitude of vibrations. The third factor is the magnitude of mass on the bridge itself. The fourth factor is the grade of evenness of the road carpet which diminishes or increases the hammering blow of the wheels. There are many other factors like flat and irregular wheels, eccentric wheels, unbalanced engines, cars, etc. These are all factors which affect the dynamical force and which we are used to call by the name "impact." The solving of the elastic problem of a bridge due to impact in resolving them in strain and stresses similarly to statical conditions, was the object of the most learned Engineers since the 17th century. We know that Euler in 1773 wrote an essay on transverse vibration in bars. In 1829, Poisson established a complete differential equation of transverse vibration in rigid bars.

Willis in 1849 was busy with the problem of finding the influence of rolling loads on bridges (*vide* Report of the Commission appointed to enquire into the application of iron to railway structures, London 1849). Willis in his report makes the assumption that if a beam is of a negligible mass, the deformation in the beam under the rolling load is the same as in the case of a statical deflection. Stokes in the same year 1849, was occupied with the same problem as Willis which can be traced from his paper "Discussion of a differential equation relating to the breaking of railway bridges." Resal in

1882, Boussinesq in 1883, Soulayre in 1889, Delandres in 1892, Clauser in 1892-1894, Zimmerman in 1896 and Land in 1899, have, by eliminating the time in the equation $X=ct$ (where c is the velocity of the rolling load), solved the complete differential equation of the 4th degree.

Phillips in 1855 and Renaudot in the same year, first attemted, in their research, to solve the vibration problem with the help of partial differential equation. (See calcule de la resistance des poutres droites, telles que le ponts, le rails etc. sous l'action d'une charge en mouvement. Ann. des mines 1855 page 467) and (Etudes de L'influence des charges en mouvement sur la resistance des ponts metallique a poutre droites, Annal. Pont Chauss. 1861 page 145). Professor Kriloff in 1905 and Timoshenko in 1911 have made very valuable research work which throws much new light on the theory of bridge vibration which is the chief factor causing complication in estimating the magnitude of the force in impact.

With all the above mentioned valuable information in hand, there is still no clear and definite figure or formula of impact derived for bridges of different types and classes in this country. After so many years of research work, the Bridge Standard Committee in India in 1932 proclaimed that as regards impact the Committee did not see their way to differentiate between different classes of road bridges, such as steel, timber, masonry and reinforced concrete (see graphs Nos. 1, 2, 3). There is a special prejudice against reinforced concrete bridges in the railways and the prevalent idea in India seems to be that reinforced concrete is unsuitable for railway bridge construction owing to the "danger of impact effect." This is not in agreement with the finding of the Bridge Stress Committee on the Continent which shows that the large increase of stress, when the period of the applied pulsating force coincides with the natural period of vibration of the bridge, does not apply to reinforced concrete bridges, owing to their mass and stiffness which make their period of vibration so small, that it is unattainable with any engine speed in practice.

The Bridge Standard Committee in India has issued a formula for impact $\frac{65}{45+L} \times 0{\cdot}5$ for all classes of road bridges, which is a reduced formula of the American Railway Engineering

Association issued in the years 1907-1909. This formula is $\frac{50}{L+125}$. The history of this formula starts about 30 years ago when the American Railway Engineers and Maintenance of Way Association had to produce some kind of formula which should satisfy the average condition of railway bridges, due to the increase in speed and traffic and heavy locomotives. This formula has been derived with the help of a stressometer by letting locomotives pass over different bridges with the same speed, but on further experimental investigations, when speed was considered, it was found that, for a rolling load passing the bridge at 10 to 15 miles per hour, the recorded impact was practically zero. These results are quoted from the American Committee 1911, when testing 21 plate-girder bridges up to 100 ft. spans and 24 trussed bridges from 100 ft. to 250 ft. long. As the only factor in the above mentioned formula is the span of the bridge it is evidently clear that this formula will not satisfy if the factor of time or velocity is taken into consideration. It is also very astonishing that after so many British scientific men have, by their original investigations on impact increased the amount of knowledge on this subject, the Ministry of Transport in England in 1919 could not find a better formula for Road bridge than the Americans.

To be clear on the point of what impact really consists we will first try to explain the phenomena caused by impact on steel bridges. We are aware that when a rolling load passes a bridge a vibratory motion is produced in the bridge; when weight falls on a steel girder it causes vibration also. The vibration of the 2nd case will soon die out. This kind of vibration is called "free transverse vibration" (graph No. 5). The vibration can be measured or calculated. The original equation of vibration is a differential equation of the 4th degree which we are not going to try and solve as the solution can be found in any book on the subject of theory of vibrations, but we will produce here the formula with which the amount of vibration per second can be estimated, *viz.*

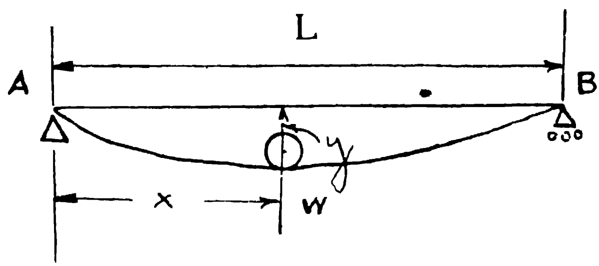
$$V_b = \frac{\pi}{2 L^2} \sqrt{\frac{g}{w} E I}$$

where V_b = number of vibrations per second.

L = span in feet.
g = acceleration = 32·2 ft. sec. per sec.
E = The modulus of elasticity.
I = The moment of inertia or second moment of area of cross section.
w = The weight of girder in ton/feet.

From the above formula it will be seen that the number of vibrations increases with the increase of bending resistance and decreases with the increase of mass of the girder. The experimental results on railway bridges of different spans as shown in the table No. 1* are a proof of the correctness of this formula, as well as of others.

SKETCH No. 1.



An investigation was made on bridges unloaded and loaded with a distributed load Wdt so as to show the decrease of vibration with the increase of mass. From table No. 1 and graph No. 5 it will be seen that in bridges of small spans the number of vibrations is much greater. As regards the number of vibrations between loaded and unloaded bridges of smaller spans the difference is also considerable. The difference disappears only in a span of about 500 ft. Although the above formula has been derived from investigations of a bar it can be applied not only for full girder bridges, but also for trussed bridges. Engineer Hawranek when testing a trussed bridge with half parabolic booms, found that the number of vibrations V_b lay between 3·95 and 4·05. If we adopt Eng. Hawranek's figure as correct, the weight for one trussed beam per ft. = W = 3·24 tons, making the moment of inertia of a full girder of the same magnitude, which will cause the same statical deflection as the half parabolic girder which has

L = 152 feet.
I = 19·63 ft.^{4} and the modulus of elasticity of the steel.

* Table of various factors increasing the statical deformation on a Steel Bridge.

$E = 0{\cdot}1836 \times 10^7$ ton/ft.

Substituting this in our formula we have

$$V_b = \frac{\pi}{2L^2}\sqrt{\frac{g\,E\,I}{w}} = \frac{\pi}{2 \times 152^2}\sqrt{\frac{32{\cdot}2}{3{\cdot}24} \times 0{\cdot}1836 \times 10^7 \times 19{\cdot}63\text{ft.}^4}$$

$$= 4{\cdot}04$$

which is near the observed figure of vibrations and, therefore, we are justified in saying that when estimating the number of vibrations in a girder bridge they behave in the same manner as simple bars.

Now we may step further and analyse the case of a forced vibration. By a forced vibration is to be understood a number of vibrations caused by periodical disturbances of a force; shortly expressed, vibrations having the same frequency as that of a disturbing force. An extreme case will be when resonance occurs.

The theoretical investigations of stresses due to this kind of vibration derived from the same differential equation:

$\left(\frac{w}{g}\frac{d^2y}{dt^2} + EI\,\frac{d^4y}{dx^4} = W\,(xt) \right)$ show that the right-hand member $W\,(xt)$ represents the influence of a rolling load on a girder. After many transfigurations, eliminations and assumptions, it was possible from this equation to form an idea about the magnitude of deflection due to the rolling load. The important assumption was made that the load changed its position on the bridge, with an infinitely small velocity, and the weight of the bridge W was negligible in comparison with the great weight of the rolling load. A much simpler derivation of the deflection due to the forced vibration impact has been derived by Timoshenko by reasoning out the following facts.

In an infinitely small speed in movement (sketch No. 1) the vertical forces of the impact must also be infinitesimal and the deflection under the load can be estimated after the well-known formula

$$y = W\,\frac{(Lx - x^2)^2}{3LEI}$$

We would not be far wrong in assuming that if the velocity per second (V feet/sec.) of the rolling load W is infinitesimal, the additional deflection due to the impact can be calculated with the same formula as just mentioned. The additional over-weight of the rolling load causing additional deflection will be :

$$W_o = -\frac{W}{g}\frac{d^2y}{dt^2}.$$

As $x = vt$ and eliminating y with this value we get

$$W_o = \frac{Wv^2}{g}\frac{d^2y}{dx^2} = -\frac{Wv^2}{g}\frac{2W}{3LEI}(L^2 - 6Lx + 6x^2)$$

$$\text{max. } W_o = -\frac{Wv^2}{g}\frac{WL}{3EI}$$

total maximum pressure on the beam is in $x = \frac{L}{2}$, then the total

$$\text{load} = W + W_o = +W\left(1 + \frac{v^2 WL}{3EIg}\right) = W\left(1 + \frac{16v^2}{L}\frac{yst}{g}\right)$$

$$= W(1 + 1/a)$$

where $yst = \frac{WL^3}{48Ey}$ and $1/a = \frac{16v^2}{L}\frac{yst}{g}$.

Considering the up-to-date velocities of the rolling loads and the magnitude of bridge construction, $\frac{yst}{L}$ the value of $1/a$ is very small and this formula gives us nearly exact results. A more exact method of solving this problem for a beam of a negligible weight, being deformed by a heavy axle load, was given by G. G. Stokes, which we are now able to put in a simple form of equation :

$$W + W_o = W\left(1 + \frac{1}{a-3}\right)$$

In the case of an axle load the pressure W_1 on the axle through the springs has to be considered. This pressure may be considered unaffected in time of the deformation of the beam or bridge, and the formula will be :

$$W + W_o = W_1 + W\left(1 + \frac{1}{a-3}\right).$$

W_1 is a multiple of W and even by very small magnitude of a, this additional force causing impact, is negligible.

Zimmerman has calculated and found that when a locomotive with a speed of 65 miles per hour passes a girder beam of 12″ high, the impact causes an additional deflection which is only 14% of the statical.

With the same elementary method Prof. Timoshenko calculates the maximum bending moment due to impact caused by forced transversal vibration as:

$$M_{max} = \frac{WL}{4}\left(1 + \frac{1}{a-3}\right) + \frac{W_0L}{8}\left(1 + \frac{5}{4}\frac{1}{a}\right).$$

The first member of the right-hand equation represents the moment due to a rolling load and the second, the bending moment due to dead load.

These formulae give reasonable results only when the weight of the girder is negligible in comparison with the weight of the rolling load. In big spans the weight may increase to such an extent that the total maximum bending moment due to dead load will be much greater than the rolling load. In this case the additional load of the impact is negligible and the bridge should, therefore, be calculated according to vibration caused by alternating forces. How this is done has been explained in Cletsch's book, page 609. For judging the condition when the forced vibration will obtain its biggest amplitude it is necessary to find the period of free transverse vibration which can be expressed as follows:

$$P = 2\pi\sqrt{\frac{\lambda}{g}} = 2\pi\sqrt{\frac{WL}{EAg}}$$

where $\frac{WL}{EA} = \lambda$.

Table No. 2 shows the period of transverse free vibration for different railway bridges of different spans. It has

been assumed that the depth of bridge girders = 0·1L and the permissible stress in steel was taken to be 12,000 lbs./sq. in.

Table No. 2.

Span L in feet	32·8	65·6	131·2	196·8	262·4	328·0
Period of Trans. Vibr. per sec. P	0·046	0·079	0·29	0·181	0·226	0·270
Velocity 22 miles per hour. *a*	0·023	0·020	0·016	0·015	0·014	0·0135
Velocity 65 miles per hour. *a*	0·069	0·060	0·048	0·045	0·042	0·040

In the case of resonance this will only be possible when

$$P = \frac{2\,L}{v}.$$

From the table it is to be seen that the *up-to-date velocity* of the locomotive cannot produce resonance as $a = P : \frac{2\,L}{v}$ is very small.

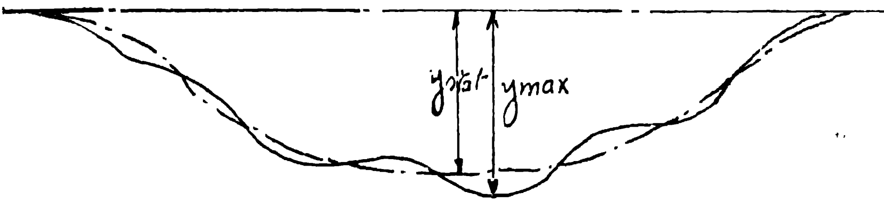
This calculation shows also that the statical deflection and the deflection from a forced vibration can be represented by a formula which is exact enough, expressed by

$$y \text{ dynam.} = y \text{ stat } (1 + a); \quad yst = \frac{W\,l^3}{48\,E\,I}.$$

A load in a girder produces sinkage under the charging point. This sinkage or deflection reaches a maximum and disappears when the rolling load leaves the girder, but the girder will still be under the action of forced vibration. The amplitude due to dying out movements is a little greater than the deflection due to a motionless load. The difference is only 2%. With this forced vibratory deflection we must also take into account the deflection due to the free transverse vibration which is of a still smaller amplitude. The result is that the two vibrations according to deflection are not of the simple

curve but as shown in the sketch No. 2, and from the same sketch is to be seen that the deflection is a little away from the middle of the span.

SKETCH No. 2.



This undulated curve has been derived after transformation of the equation

$$\frac{w}{g}\frac{d^2y}{dt^2} + E\,I\,\frac{d^4y}{dx^4} = w + W\,(xt).$$

(Where w is the weight of dead load of the girder and W (xt) is the weight of a rolling load causing forced transverse vibration), into the form :—

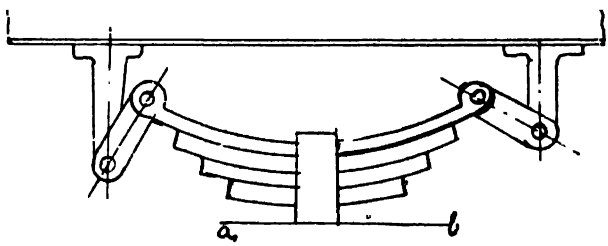
$$y = \frac{2WL^3}{EI\pi^4}\left\{ \sum_{k=1} \frac{\sin\frac{k\pi}{L}\sin\frac{k\pi ct}{L}}{\left(1-\frac{a^2}{k^2}\right)} \quad \sum_{k=1}^{\infty} \frac{\sin\frac{k\pi x}{L}\,\mathrm{Sin}\,\frac{k\;k\pi ct}{a\;L}}{k^5\left(1-\frac{a^2}{k^2}\right)} \right\}$$

a represents the value of the dynamical behaviour of the girder, which is always smaller than one and decreases with the increase of span. On a span of 6·5 ft. $a = 1/11$ and is $1/20$ when the span is about 495 ft.

A spring arrangement (sketch No. 3) in a carriage has an eliminating effect when producing impact and a careful and effective arrangement of springs between the wheel axle and the body of the carriage containing the engines etc. can minimise the impact to such an extent that its value will be practically negligible. The modern motor cars and motor lorries are sufficiently provided with such spring arrangements and with tyres in addition. We may state that no impact is caused by these vehicles on a road bridge. As regards electric tramcars, locomotives and steam rollers, the spring effect may not be

of such a complete arrangement and, therefore, we may not be justified in ignoring it at all, but if sufficient damping arrangements are made the impact may also be neglected. The spring effect on impact can be traced as follows :—

SKETCH No. 3.



The vibratory motion of the bottom area *a b* of the spring in connection with the wheel axle will be the same as the girder. This will induce forced vibration in the ends of the spring with which the carriage is rigidly connected. The vibration is of a type represented by the formula:

$$a \sin 2\pi v t.$$

This is a sinus form of motions which a girder bridge makes when a rolling load passes over it.

If V_b is the number of free transverse vibrations of the weight W acting on the spring, the swing of the load will be of the type expressed by the formula

$$a \frac{v'^2}{v^2 - v'^2} \sin 2\pi v' t.$$

(See Autenrieth—Ensslin: Technishe Mechanik 3 aufl page 467).

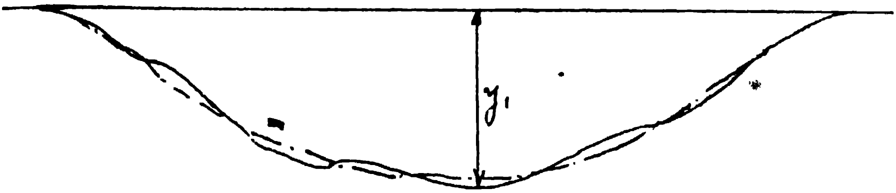
The relation between the amplitude of the forced and free vibration of the girder is expressed by the formula

$$r = \frac{\left(\frac{v'}{v}\right)}{1 - \left(\frac{v'}{v}\right)^2};$$ as $v > v'$, then r will be less than 1.

This means that a weight on a spring vibrates much less than the girder. The effect of the spring can be visualised

on the diagram (sketch No. 4) which shows the tendency to flatten the waving form of the vibration minimising the deflections. The period of vibration of a load on a spring is

$$P' = 2\pi\sqrt{\frac{yst}{g}}$$



yst = statical deformation of a spring.

In bridges of small spans say up to 82 ft. the reduction factor is smaller than 1/8* but increases rapidly with the increase of the span and, therefore, for Railways it is important that the carriages passing small span bridges should be very well provided with springs if impacts are to be avoided.

We know that the mass of a load W is expressed by the formula $\frac{W}{g}$ and its velocity is r $\frac{d^2y}{dt^2}$ where r is being used as an eliminating factor. We get from this the influence of a rolling load due to its momentum

$$W_1 = w\left(1 - \frac{rd^2y}{gdt^2}\right)$$

and after a transformation is made in the differential equation of vibration in a bar which is

$$\frac{w}{g}\frac{d^2y}{dt^2} + EI\frac{d^4y}{dx^4} = W(xt)\left(1 - \frac{rd^2y}{gdt^2}\right),$$

we arrive at the expression

$$\frac{d^2y}{dt^2} = \frac{2W}{wL}g\left[-a^2\sin\frac{\pi ct}{L} + a\sin\frac{1}{a}\frac{\pi ct}{L}\right]\sin\frac{\pi x}{L}$$

The formula $-\frac{a^2\sin\pi ct}{L}\cdot\frac{2Wg}{wL}\sin\frac{\pi x}{L}$ expresses the velocity of a forced vibration due to a momentum and the

*See table No. 1

other part of this formula is the free transverse vibration. In the middle of the span when $x = ct = \frac{L}{2}$ the velocity of forced vibration will be

$$\frac{r}{g}\frac{d^2y}{dt^2} = -\frac{2W}{wL}a^2.$$

From this it is to be concluded that the magnitude of the velocity depends on the relationship of the rolling load W to the girder weight wL. It is also obvious that in this equation the total weight W of the rolling load includes the load on all the axles but not a single axle as we often take in the calculations, and therefore a correction is necessary. If $W = \frac{4M}{L}$ is brought into the form $-\frac{8M}{wL^2}a^2$, this formula will express the necessary correction. The negative sign signifies that the momentum is acting downwards. The amplitude of the forced vibration is a little greater than the statical deformation. Therefore the formula $\frac{8M}{wL}a^2$ is sufficiently correct to express the magnitude for the deformation. As we usually express the deflection in percentage the deflection due to the momentum will be

$$100\frac{M}{wL^2}a = F_3$$

From table No. 4 it is to be seen that the increase in deflection due to the momentum is, in a span of 6·56′, about 17·5% which decreases with the increase of span. In a span of 492′ it is hardly 0·23%. In the same way momentum of the free transverse vibration is found, but in this case we are justified in taking the load of only one axle into account. The equation for this case will be

$$\frac{r}{g}\frac{dy^2}{dt^2} = \frac{2W}{wL}a\sin\frac{1}{a}\frac{\pi ct}{aL}.$$

This additional acceleration reaches its maximum when

$$\frac{\pi ct}{aL} = \frac{\pi}{2}.$$

In the case of a string of rolling loads which is not excluded in bridges of big span, the equation will be

$$W_1\left(1+\frac{2rW_1}{wL}a\right)+W_2\left(1+\frac{2rW_2}{wL}a\right)+\ldots$$

Here is the influence of the mass action depending on the ratio

$$\frac{2\,r\,W}{w\,L}:1.$$

In this unfavourable form the summation of the separate loads is possible when the distance L_1 is of such a nature that $\frac{L_1}{c}=a\frac{2\,a\,L}{c}$ which signifies the frequency of a free vibration. This is a very rare case. By adopting a correction factor we may generalise the formula which is $\frac{r}{g}\frac{d^2y}{dt^2}=\frac{2r\,W}{w\,L}a$ where W is the weight of the maximum axle. In a bridge of a smaller span the influence of springs is great. Therefore we prefer to take the elimination factor into account. In the table No. 1, it is assumed that 80% of the load rests on springs. In the table the values are :

$$F'_3 = 100\,\frac{\gamma'_3}{\gamma'}=100\,\frac{2{\cdot}16}{wL}\quad\text{r. } a \text{. of a load resting on springs.}$$

$$F_3'' = 100\,\frac{\gamma''_3}{\gamma'} = 100\,\frac{2{\cdot}4}{wL}\quad\text{r. } a\text{. of a load without springs.}$$

$$F_4=\frac{y'_3+y''_3}{\gamma'};\ F_5=\frac{y_3}{y\text{ st.}}$$

Where $y'_3+y''_3$; .... are additional deflection.

Concluding the above investigations we can now state that the impact on a simple railway girder bridge where the rolling load is directly moving on the girders the sum of the dynamical actions will be

$$I=\left(F_1+F_2+F_3+F_4+\frac{\triangle M}{M}\right)$$

and if we denote the rolling load W the increased amount due to impact will result in W (1 + I).

The expression $\frac{\triangle M}{M}$ is the increase in percentage of bending moment due to the centrifugal force of the driving and coupled

wheels of the locomotive. If we consider that all these results obtained can be applied to a steel bridge then in the case of 10″ road metal consisting of 4″ stone setts laid on 4″ broken stone and 2″ sand, the amount of impact will be absorbed and reduced by about 36% and if the impact I for example is calculated to be 50%, only 50%—36%=14% of impact will be available. (See graph No. 6).

The same exact methods of finding out the additional deformation due to a moving load have been applied to a number of reinforced concrete bridges on the Continent. An example of an impact test made in Winterthur, Switzerland, is the worst case as the road carpet is of 3″ rough stone setts directly laid on the concrete slab. Nevertheless the additional maximum deflection is only 21% of the statical of the same rolling load (see Drawing No. 1).

$$\text{If } Y = \frac{c.\,WL^3}{E\,I},$$

$$W(1+i) = \left(y_{st} + \Sigma\, y_d\,\frac{100}{n}\right)\frac{E\,I}{c\,L^3}$$

$$= \frac{n}{100}\left(y_1+y_2+y_3\ldots\right)\frac{WL^3}{E\,y}\,c, \text{ which is only } 21\%$$

(where c is a numerical factor depending on the rigidity of the beam). As the deformation y in a steel bridge is much greater than in a reinforced concrete bridge and often can be of such magnitude that the road carpet on the bridge may be greatly affected which is often the case, it is understood why in steel bridges the deformation y has to be kept in control by demanding a bigger impact knowing that this impact will never be realised. In reinforced concrete bridges the deformations are very negligible even when the birdge is loaded near to destruction. Therefore, the preservation of the road carpet in reinforced concrete bridges will be a factor of economy and the thickness can also be reduced to a minimum as there is no need for a great damping mass to reduce the vibration, but the example of the concrete bridge in question will speak for itself. The reinforced concrete bridge as shown in table No. 3 and Drawing No. 1 is an overland bridge over a railway track. The bridge consists of 5 different spans. The impact test was made by rolling two steam rollers of 15 and 15·5 tons and motor lorries

of 9·5 tons with a trolly of 7·7 tons attached. From the deformation the modulus of the elasticity has been found to lie between 3,400,000 and 4,100,000 as against the usual assumption E_C = 2,000,000 lbs./foot. From the record table No. 3 we find that the dynamical effect represents the ratio of the vibration amplitude to the maximum deflection of the ordinate recorded on the point of application of load. The dynamical effect on smaller spans is less than on the girder rims. The explanation for this is due to the lack of stiffness in the girder rims caused by the road slab. The maximum dynamical effect is about 21% which in comparison with another test on reinforced concrete bridges is to be considered very high. The average value of an individual girder is only 11% to 15% which is also considered to be high and this is due to the very high ratio between the span and the height of the beam which is $\left(\frac{L}{h} \quad 21{\cdot}2\right)$ which is also very unusual. The roadway was very uneven due to the surface plaster being scaled off. We have taken this unfavourable test example of impact which was carried out in the year 1924, nearly 12 years ago. Since then other examples have shown that the impact is much less than 10% on bridges with smaller spans with a velocity of 30 miles per hour. In any case the impact of 21% is still far away from the dictated impact of 60% or 50% and adopted in this country as in the case of the Chandmari Bridge in Calcutta. The Chandmari Bridge was designed by the Author of this paper for carrying 3 trains of 15 British units which is equal to nearly 1.3 ton per sq. ft. if distributed. Such a rolling load does not exist in India and I do not think that it will come even in half a century. Such heavy loads do not exist even in the most technically advanced countries like France, Germany and Italy. Then why design such heavy bridges which only affect the foundations unnecessarily and make the cost prohibitive? We have often been told that by commanding a higher percentage in impact the factor of safety of the bridge is automatically increased. This may be very well for steel bridges where the factor of safety starts to decrease after its *status nascendi* which is shown in the diagram No. 4.

In any case it is not justified to apply an imaginary increase in impact on reinforced concrete bridges and the most correct method of having more rigid bridges would have been

to specify for steel bridges, when found desirable, with a greater factor of safety than 3 or 4.

In conclusion it is suggested that following impacts should be adopted for different types of R. C. bridges :

R. C. GIRDER AND FRAME BRIDGES.

(1) Slabs up to 30′ span without metal road 40% impact should be taken. This is also for longitudinal and transverse beams. Slabs up to 30′ span with metal road 40% impact should be taken. A subtraction according to the thickness of the metal should be made as per graph No. 6.

(2) Beams from 30′ to 40′ without metal road 30%, with metal road a subtraction should be made.

(3) Beams from 40′ to 60′ without metal road 25%, with metal road a subtraction should be made.

(4) Beams from 40′ to 80′ without metal road 20%, with metal road a subtraction should be made.

(5) Beams from 80′ to 100′ without metal road 15%, with metal road 10″ thick no impact.

(6) Beams from 100′ to 120′ without metal road 10%, with metal road 5″ thick no impact.

(7) Beams from 125′ and up, no impact with 3″ asphalt road.

BOW STRING GIRDER.

Deck slab up to 30′ span without metal road 40% impact, with metal road subtract according to thickness.

Arch bridge with open span—

Up to 100′ span—15% impact
with metal road subtract according to the thickness.

From 100′ to 150′ span—10% impact
with metal road of 10″ thick no impact.

From 150′ span—no impact.

Arch bridge—

Up to 150′—10% impact.

From 150′—no impact.

Bridges for Industrial Railways without metal road. Girder and Frame Bridges.

	Wooden Sleepers	Steel Sleepers
Up to 30′ span	60%	65%
From 30′ to 50′	50%	55%
From 50′ to 100′	40%	45%

With metal road deduct according to graph No. 6.

Bow String Girders including Hangers.

	Wooden Sleepers	Steel Sleepers
Up to 30′ span	60%	65%
From 30′ to 100′	50%	55%
From 100′ to 200′	40%	45%
From 200′ to 225′	30%	35%
From 225′ to 250′	25%	30%
From 250′ to 300′	10%	15%

Spandrel Arch Bridges—The same as for Bow String Girder Bridges.

Arch Bridges.

	Wooden Sleepers	Steel Sleepers
Up to 100′	20%	25%
From 100′ to 150′	15%	20%
From 150′ to 175′	10%	15%
From 200′	No impact.	....

It is understood that the joints of the rails have to be welded, if this is not possible the impact will have to be increased by 10%. The metal road has to be made absolutely smooth and the road carpet improved as soon as its deterioration is detected, which is possible with the large staff of the P. W. D. in India.

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DISCUSSION ON IMPACT FOR REINFORCED CONCRETE BRIDGES.

Mr. W. A. RADICE said that the Author was to be congratulated on his knowledge of the history of the mathematics of the subject of the Paper and on his brilliant treatment of the theoretical aspect of this important question.

The speaker had been encouraged to submit the following comments by the fact that he had followed closely and at times taken part in the investigation into the impact effects on railway bridges carried out over many years by the Bridge Engineers of the Indian railways. In the year 1936, with Mr. W. J. Turnbull, then of the Concrete Association of India, he was entrusted by the Council of the Indian Roads Congress with the task of drawing up a Standard Specification for road bridges in India. Their draft was submitted to a revising Committee consisting of Mr. C. P. M. Harrison, Chief Engineer, Bengal P.W.D., Mr. R. A. Fitzherbert, Dy. Secretary to the Government of Bombay, P.W.D., and Mr. G. B. E. Truscott, Chief Engineer, Travancore State, and after a few minor alterations, was approved by the Council of the Indian Roads Congress. This Standard Specification was in the press and would be available in a few weeks' time for distribution to members of the Congress and for sale to the public. The object of this specification was to present to the road engineers of India a Standard Bridge Specification bearing the Imprimatur of the Congress, whose members comprise, in an unofficial capacity, the senior bridge engineers of India, with the hope that it would eventually be adopted generally throughout the provinces.

Mr. Radice continued that the Author had confined himself in his Paper nearly entirely to the theoretical aspect of the subject, and he (Mr. Radice) whilst agreeing whole-heartedly with the theoretical development, desired to add some comments on the practical aspects of the problem.

Throughout his career it had been the invariable practice of Mr. Radice to estimate, as far as possible, the cash value of theoretical conclusions. As a result he had found that considerable discussion and theoretical work were often devoted to considerations of small monetary importance. When faced with the task of recommending an impact factor formula for the Standard Specification for Road Bridges for the Indian Roads Congress, he estimated the actual difference in cost between the adoption of the Railway Bridge Standards Committee's formula mentioned on page 92 *viz.* :—

$$\frac{65}{45+L} \times 0.5$$

and of one half this amount. For this purpose 16 typical reinforced concrete bridges were analysed. The bridges were selected to cover as ample a range of spans, road widths and types as possible. The following was a brief description of each :—

1. One central bowstring girder span of 80 feet and two slab and beam approach spans of 36 feet 6 inches. 20 feet roadway flanked by 3 feet footpaths. 10 inches Waterbound Macadam.

2. Three half through plain beam spans of 66 feet, webs of beams being pierced. 23 feet roadway flanked by 2 feet 6 inches footpaths. 10 inches Waterbound Macadam.

3. One skew rigid frame span of 66 feet 9 inches with 10 ribs. 39 feet 4 inches roadway flanked by 4 feet footpaths. 20 inches Waterbound Macadam.

4. Three continuous beam and slab spans of 35 feet, 38 feet 4½ inches and 35 feet. 36 feet roadway, no footpaths, 4 inches Tar Macadam.

5. Six continuous stiff frame spans of 47 feet 7 inches, 55 feet 1½ inches, 55 feet 1½ inches, 55 feet 1½ inches, 55 feet 1½ inches, 47 feet 7 inches, 16 feet 9 inches road flanked by 1 foot 6 inches footpaths. 10¼ inches Tar Macadam.

6. One stiff frame span of 137 feet 9 inches with end cantilevers each of 49 feet 3 inches slab and beam construction. 16 feet 6 inches roadway flanked by 2 feet 9 inches footpaths. Concrete surfacing (Monolithic with slab).

7. Seven bowstring girder spans of 131 feet 8 inches each. 17 feet roadway, no footpaths. 10 inches Waterbound Macadam.

8. One bowstring girder span of 242 feet 9 inches. 16 feet 5 inches roadway, no footpaths. Concrete surfacing (Monolithic with slab).

9. Three open spandrel arch spans of 55 feet 9 inches each. 16 feet 6 inches roadway flanked by 2 footpaths of 2½ feet each. Surfacing consists of sand cushion and Tar Macadam 20 inches total thickness.

10. One central open spandrel arch span of 164 feet with one slab and beam approach span of 23 feet 3 inches at one end and two of 26 feet 3 inches and 24 feet 6 inches at the other. 17 feet roadway, no footpaths. 9 inches Waterbound Macadam.

11. One open spandrel arch span of 157 feet 6 inches. 34 feet 6 inches roadway flanked by 6 feet footpaths. 4 inches Tar Macadam.

12. One central open spandrel arch span of 170 feet 6 inches with one slab and beam approach span of 15 feet 5 inches at each end. 32 feet 10 inches roadway, no footpaths. 4 inches Tar Macadam.

13. Three open pandrel arch spans of 200 feet each. 26 feet 3 inches roadway flanked by 3¼ feet footpaths. 4 inches Tar Macadam.

14. Open spandrel arch span of 235 feet. 18 feet roadway flanked by 3¼ feet footpaths. 1½ inches sheet asphalt.

15. One solid spandrel arch span of 72 feet 2 inches. 24 feet 6 inches roadway, no footpaths. 12 inches Waterbound Macadam.

16. Five open spandrel arch spans of 123 feet 4 inches each. 16 feet roadway, no footpaths. 12 inches Waterbound Macadam.

In applying the Railway Bridge Standards Committee's impact formula to the above examples of the bridge builders'

art, it was thought desirable to slightly modify it so as to take into account the largely varying widths of the various roadways. The formula used was

$$I = 0{\cdot}5 \times \frac{65}{45 + L\left(\frac{n+1}{2}\right)}$$

where n was the number of traffic lanes which could use the bridge simultaneously.

The analysis showed that the above bridges consisted of :—

24,938	tons of concrete
1,270	tons of steel reinforcements
3,896	tons of surfacing materials
30,104	tons total dead load
6,411	tons of live load
2,388	tons of impact allowance
8,799	tons of live load including impact

giving a total load carried of 38,903 tons.

It would be noticed that the impact allowance was only 6·13% of the total load.

Pricing the reinforced concrete at Rs. 40/- per ton for the concrete and Rs. 300/- per ton for the reinforcements the total cost of the superstructures of these 16 bridges was Rs. 10,78,550/-.

If the impact allowance, as given by the above formula was halved, the resulting saving was Rs. 25,615/- which was only 2·175% of the cost of the bridges.

Considering individual bridges, the greatest saving in cost was in No. 4 where the use of continuous spans produced a very light superstructure. The saving in this case amounted to 13·75%.

Bridge No. 7 came next with a saving of 2·83%, closely followed by No. 1, No. 2, No. 10, No. 12 and No. 15 which vary from 2·66% to 2·39%. No. 5, No. 6, No. 8, No. 9 and No. 26 gave savings between 2% and 1%, No. 13 1% and the lowest were Nos. 14 and 3 which gave savings of 0·40% and 0·20% respectively.

Having obtained an approximate value of the cost of varying impact allowance, it was proposed to compare the results obtained by the use of the above formula with the Author's recommendations, but before doing so, two important points required notice.

The first point was that the Author did not state the width of bridge to which the recommended allowances for impact were to be applied. It seemed reasonable to allow reductions in the case of wide bridges carrying several lines of traffic since the probability of each line of traffic carrying simultaneously the maximum live load in such a position as to stress the member under consideration to a maximum must decrease as the number of lanes of traffic increased. In the subsequent comparison it had been assumed that the recommended percentages were for bridges carrying two lines of traffic.

The second point was the proposal to diminish the impact allowance for absorption of impact effects by the road surfacing. Whilst agreeing that theoretically this was correct, the speaker considered that on practical grounds the presence of a Water-bound Macadam surface had nearly invariably an opposite effect. On page 107 of the Paper the Author rather qualified that permissible relaxation by the saving clause :

> "It is understood that the joints of the rails have to be "welded, if this is not possible the impact will have to be "increased by 10%. The metal road has to be made "absolutely smooth and the road carpet improved as soon "as its deterioration is detected, *which is possible with the "large staff of the P.W.D. in India.*"

Whilst most of the engineers would agree with the possibility of immediate repairs in road surfaces on bridges none of those who travelled much on Indian roads would agree as to its probability nor was it thought that the members of the P.W.D. would subscribe to the statement that they had a large staff available for immediate repairs. The speaker's experience was that the macadam *surfacing on* bridges *deteriorated more rapidly* than on the rest of the road, was more difficult to repair and generally presented a surface pitted with potholes.

This was undoubtedly an important point, because the Indian railway bridge engineers had analysed and measured

the various factors which produced impact effects in railway bridges and had found that the effects caused by :—

1. Inclination of the connecting rod •
2. Unbalancement of the moving parts
3. Lurch due to the locomotive springs
4. Rail joints and inequalities in the track

when added together produced a sum nearly equal to the observed total impact effects, leaving only a comparatively small remnant due to the rapid application of the static load.

In a road vehicle the first influence was non-existent and the second practically negligible. Consequently the third and fourth influences became predominant and the state of the road surface, the principal cause of impact effects. It was the impossibility of making rational assumptions as to the irregularities of road bridge surfaces, which made theoretical results of small practical value in assessing what provision to make for impact in road bridges, unless the surface could be guaranteed to be smooth such as was provided by floor systems of the battledeck and trilok types.

The Author agreed that the effects of the rapid application of the load became negligible in the main girders or arch ribs of heavy concrete road bridges. To lay down that the chief cause of impact, roughness of surface, was also negligible by assuming that bridge surfaces were smooth and were kept so, was against the evidence of one's senses and a counsel of perfection impossible of realisation in a practical world.

Turning away from debatable points and coming back to actual practical results, a comparison was submitted between the impact factors yielded by the formula adopted by the Indian Roads Congress in their Standard Specification and the Author's recommendations.

It should be noticed that the Indian Roads Congress formula defined L as the length of that part of the bridge which must be loaded to produce the maximum stress in the member or part under consideration. It had therefore been assumed that the percentages of impact recommended by the Author for various types of bridges of varying span referred to the main girders or arch ribs only, the floor slabs, stringers and cross girders of the floor system and the cross girder hangers or columns connecting their ends to the main girders or arch ribs being always dealt with under item (1) on page 106.

The Congress formula gave the following percentage increases of the live load to provide for impact :—

Span of Bridge.	Width of Roadway in lines of traffic.			
	1 line.	2 lines.	3 lines.	4 lines.
10 feet	50%	50%	50%	50%
20 „	50%	43·3%	38·2%	34·2%
30 „	43·3%	36·1%	30·9%	27·1%
40 „	38·2%	30·9%	26·0%	22·4%
50 „	34·2%	27·1%	22·4%	19·1%
60 „	30·9%	24·1%	19·7%	16·7%
70 „	28·3%	21·7%	17·6%	14·8%
80 „	26·0%	19·7%	15·7%	13·3%
90 „	24·1%	18·1%	14·4%	12·0%
100 „	22·4%	16·7%	13·3%	11·0%
120 „	19·7%	14·4%	11·4%	9·4%
140 „	17·6%	12·7%	10·0%	8·2%
160 „	15·7%	11·4%	8·9%	7·3%
180 „	14·4%	10·2%	7·9%	6·6%
200 „	13·3%	9·4%	7·3%	6·0%

Comparing these percentages as given for bridges wide enough to carry 2 lines of traffic, with those recommended in the Paper and ignoring the proposed reductions for a metalled surface for the reasons adduced above, the following was obtained :—

	Percentage recommended in Paper.	Road Congress formula.
Girder and Frame Bridges.		
(1) Slabs, stringers and cross girders up to 30 ft. span ..	40% ..	50% to 36·1%
(2) Beams 30′ to 40′ ..	30% ..	30·9%
(3) „ 40′ to 60′ ..	25% ..	27·1% to 24.1%
(4) „ 60′ to 80′ ..	20% ..	19·7%
(5) „ 80′ to 100′ ..	15% ..	18·1% to 16·7%
(6) „ 100′ to 120′ ..	10% ..	14·4%
(7) „ 125′ and up ..	0 ..	13%

Bow String Girders.

Arch ribs up to 100′ span	..	15%	..	as above for beams
Arch ribs from 100′ to 150′	..	10%	..	16·7% to 12%
Arch ribs above 150′	..	0	..	10·2% to 9·4%

The great mass of road bridge spans were under 100 ft. so that it could be said that on the whole the difference between the two sets of values was not startling except in the few rare cases of spans exceeding 100 ft.

Taking it all in all the use of the Indian Roads Congress formula, which was also that approved and used by all Indian railways for road overbridges and combined rail and road bridges, instead of the percentages recommended in the Paper would make practically no difference in spans up to 100 ft. with 2 lines of traffic, would cheapen the cost of bridges capable of taking more than 2 lines of traffic and would increase the cost of spans of over 100 ft. by something less than 1 or 2% at most.

The Author's conclusions formed a very re-assuring confirmation of the soundness of the new Standard Specification.

Mr. Radice was in complete agreement with the Author as regards the absurd live loads and impact factors often specified in India for road bridges, the Chandmari Bridge in Calcutta quoted in the Paper being a particularly glaring example. It was just to check such inconsistencies that the Indian Roads Congress Specification had been drawn up and as it was not then available it might be of interest if the clauses defining the standard loadings were quoted here.

Road bridges had been divided into 2 classes :—

1. Bridges for all roads, metalled or unmetalled on which it was feasible for a heavy lorry to travel or on which a heavy lorry was likely to travel and which were not likely to be converted into roads with thick reinforced concrete or other equivalent foundations.

2. Bridges for roads within municipal limits of all towns, notified areas and existing or contemplated industrial areas and for roads constructed of reinforced concrete slabs or equivalent foundations or likely to be so constructed.

A light loading was considered for *kutcha* roads but the ordinary crowd load brought up the equivalent loading so near to the standard loading for the first classification that a third standard loading was not considered justified.

The two standard live loadings to suit the above classification of road bridges were as follows :—

1. The Indian Standard Loading.

   0·34 ton per linear foot of each traffic lane width of 10 ft. plus a knife-edge load of 6 tons for computing bending moments, or of 9 tons for computing shears with the limitation that for computing bending moments the total distributed load on loaded lengths of 20 ft. and under should never be less than 6·8 tons per lane of traffic over the whole loaded length.

2. The Heavy Indian Standard Loading.

   0·58 ton per linear foot of each traffic lane of 10 ft. width plus a knife-edge load of 7 tons for computing bending moments, or of 10 tons for computing shears, with the limitation that for computing bending moments the total distributed load on loaded lengths of 20 ft. or under should never be less than 11·6 tons per lane of traffic over the whole loaded length.

For all bridges, footpaths and other parts of the floor accessible only to pedestrians and animals the loading should be 84 lbs. per square foot with no impact allowance.

The way these loadings were to be applied were laid down as follows :—

In the case of main trusses or arch ribs, irrespective of the loaded length, one knife-edge load should be taken as acting in conjunction with the appropriate uniformly distributed load.

When calculating the stresses in any member of a structure the uniformly distributed load should be applied over the whole or such part of the span that would cause the greatest stress in that member and the concentrated load should be applied at the point which should cause the greatest stress in that member.

In designing floor systems the uniformly distributed load and the knife-edge load should each be divided by 10 to obtain a uniformly distributed load and a concentrated load per foot width.

The appropriate knife-edge load specified above should be taken as acting on floor surfaces and systems in the direction which would give the greatest stress in the part under consideration, except in the case of cross girders where the appropriate knife-edge load should be taken as acting along their axis.

Longitudinal stringers, etc., should be designed to carry a strip of live load of width equal to the stringer spacing, except in the case of stringers spaced at less than 5 ft. centres and where no provision was made for equalisation of deflections, in which case the stringer should be proportioned to carry a strip of live load 5 ft. wide in addition to its share of dead load. The longitudinal members at the extreme sides of the bridge floor should not be less strong than the lightest intermediate members.

Mr. A. VASUDEVAN thanked Dr. Korni, for introducing his Paper on a subject (of "Impact for R.C. Bridges") which raised a very important factor in reinforced concrete bridge design.

Ever since a study of this subject had been undertaken, there had always been two approaches to the solution of the problem tackled by it, but neither of them was able to lead investigators independently to a finality unaided by the other. Men like Professors Melan, Inglis, Zimmerman, Turneaure and Timoshenko attempted to obtain a solution of the problem from a purely theoretical and mathematical point of view and in so doing they had to make certain assumptions before the results thereof could be applied to bridge design. On the other hand the sub-committee on impact of the

American Railway Engineering and Maintenance of Way Association, the Bridge Stress Committee of Great Britain and the Bridge Standards Committee of India had conducted a large number of experiments on bridges of various spans and with different types of engines with speeds varying from 0—70 miles per hour and had formulated their results but had been handicapped in their attempt to deduce accurate general formulae from their results, which were capable of exacting mathematical analysis.

The problem of bridge impact was extremely complex and so far no exact solution of it had been arrived at. This, however, had been considered by many designers that if the co-efficient of impact could be determined exactly, it would not be of sufficient practical utility as it would differ not only for bridges of different lengths but also for each type of vehicle traversing it and for each member of the bridge. Even variations in temperatures and dimensions of girders were likely to affect. Thus what was really needed was a formula simple and sufficiently accurate in its application. Impact on railway reinforced concrete bridges might be summed up to be the cumulative effect produced by the following main causes :—

(1) Hammer blow due to—
   (a) Unbalanced locomotive drivers,
   (b) Obliquity of connecting rod;
   (c) Steam effect.

(2) Rapidity of application of load.

(3) Cumulative effect of synchronised vibration.

(4) Rough and uneven track including the effect of rail joints.

(5) Flat, irregular or eccentric wheels.

(6) Lurching or swaying of the locomotive.

(7) Increase in the load caused by the fact that the path traversed by a train was generally a curved trajectory.

The formula for increment due to impact for railway bridges used by the Indian railways was $I\ \% = \dfrac{65 \times 100}{45 + L}$ where L was the length of the span. This formula had been adopted to cover the various factors enumerated above and was mainly intended for steel girder bridges.

The speaker was one of those who believed that for resisting dynamical stresses even with a sufficient elastic cushion coming in between, *reinforced concrete was a material not quite so suited as steel, as repeated strains had a very much more deleterious effect* on reinforced concrete than on steel and *usually brought about disintegration of the ingredients.*

In the introductory portion of the article the Author had referred to a special prejudice against reinforced concrete bridges on railways and the prevalent idea in India that reinforced concrete was unsuitable for railway bridge construction owing to "danger of impact effect." This was not quite the fact. Engineers had been trying reinforced concrete slabs for bridge tops for over *10 years* and their experience had been fairly satisfactory with this although it must be admitted that in the earlier years they had to constantly watch hair-cracks that were being formed on those slabs. The speaker did admit that this probably, to a certain extent, was due to the inferior concrete and the lack of control in producing concrete that existed in those days but with modern methods of concrete control the hair-cracks might disappear and if they did so, railways would go in for reinforced concrete for their bridge work to a much larger extent than they were doing.

The speaker concluded by saying that he might be considered sceptical but he would suggest a *further 10 per cent* increase in all the impact factors suggested by the Author for R. C. railway bridges.

Mr. S. B. JOSHI said that the Paper was a valuable one from the engineering point of view; he was particularly very much interested in the history of the impact factor as described in it. As regards impact percentages suggested by the Author on page 106 of his Paper he was of opinion that there was one inconsistency, *viz.*, for slab up to 30 ft. span the factor suggested was 40% and for a beam it was 30%. So far as he knew, slabs were decidedly stronger than beams in that respect and the impact factor for a beam should be greater than that of a slab, as fully discussed in "Reinforced Cement Concrete" by Scott and as could be verified from the formula on page 93 of the Paper. With reference to the increase of strength in concrete with age as shown in graph 4, Mr. Joshi was of opinion that from the stability point of view it was not only sufficient to say

that the strength in concrete increased with age but it was necessary to prove that the bond stress also increased, because if the bond stress did not increase correspondingly, it would prove disastrous as reinforcement would tend to slip with constant reversal of stress. Also from the reversal of stress point of view the steel structure was to be preferred, but if in the concrete sufficient steel was not provided on the compression side, the result would be fatal. Again the main cause of impact was not only speed but also unbalanced machinery; when springed vehicles passed over a bridge impact was less because the spring absorbed some of the vibrations and when both spring and rubber tyres were used the impact was considerably reduced.

Mr. R. N. JOSHI said that he had his doubts about the usefulness of the formula on page 93 because the Author had not dealt with the amplitude of vibrations which was also the ruling cause of impact, because, when the number of vibrations in a structure, which was also the ruling cause of impact, increased, the amplitude decreased and *vice versa*; so that the formula which was based only on vibrations and did not consider amplitude could not be said to be entirely perfect. Since the steel structure gave sufficient warning before collapsing than the R. C. C. one, he was of opinion that the impact factor should be taken more than in steel.

Mr. R. K. NARIMAN argued that since the dead weight of concrete had a greater damping effect it was not necessary to have greater impact factor in R. C. C. than in steel.

Mr. D. S. DESAI remarked that the Paper consisted of a number of unproved assertions and a number of formulae without their derivations, and that, while the mathematical part of the Paper, as might be seen from the bibliography, was based on classical work, the Author had entirely ignored not only the Report on Impact on Highway Bridges, published in 1931 by a Special Committee appointed by the American Society of Civil Engineers, but also the work of Professor C. E. Inglis which he had published in a text-book on Impact, in 2 Papers in the Proceedings of the Institution of Civil Engineers, and in the Report of the Bridge Stress Committee which

was set up by the Department of Scientific and Industrial Research, which work formed the most notable advance which had yet been made in the study of impact.

The speaker would be glad if the Author would give some elucidation of the following statements made in his Paper :—

(*a*) The Author stated on page 99 that the road vehicles gave no impact because they were well sprung. Apart from the quite considerable unsprung weight in the wheels, axles, etc., in heavy vehicles, there were vehicles which were unsprung, such as road rollers. He enquired whether the Author had considered this.

(*b*) On page 104 the Author stated that impact might be reduced according to the increase in thickness of roadway. Graph No. 6 showed the percentage of reduction which was allowable according to him. It was not clear, however, how the Author had arrived at the net impact of 14% from the example by which he illustrated the use of this graph : according to the Author the full impact was 50%, the reduction from the graph was 36% and the net impact was 14% ; surely the proper net impact should be $50\% \left(1 - \frac{36}{100}\right) = 32\%$; further, on referring to the Author's graph No. 6, the reduction corresponding to 10″ of road metal was seen to be 25% and not 36% as given by the Author.

(*c*) On page 105 the following statement was made by the Author :—"This may be very well for steel bridges where the factor of safety starts to decrease after its *status nasendi* which is shown on diagram No. 4." This statement, for which no authority was given, could not be allowed to pass unchallenged. A well designed and well maintained steel bridge would normally remain in service until the increase in prevailing live loads had reached a point which necessitated reconstruction of the bridge : no more could be said for a reinforced concrete bridge. As one outstanding example of a steel bridge of considerable age which was still fully efficient and showed no signs of requiring renewal for many decades to come, the speaker would cite the Forth Bridge which was carrying train loads many times heavier than those for which it was designed.

The speaker had given considerable thought to the question of impact in connection with the design of road bridges and had come to the conclusion that the impact formula best suited for conditions in India was that evolved by the Indian Bridge Committee and adopted by the Indian Roads Congress in their proposed standard specification for the Construction of Road Bridges in India, *viz.*—

$$I = \frac{1}{2} \times \frac{65}{45 + \left(\frac{n+1}{2}\right) \times L}$$

with a maximum of 50%
where L = the loaded length which gives the maximum stress in the member under consideration,

n — the number of traffic lanes.

There had been much agitation among protagonists of reinforced concrete construction seeking to establish a ruling that steel bridges required to be designed with a heavier percentage of impact than concrete bridges, and it had been suggested that the above formula gave percentages of impact which were unjustifiably high for use in the design of reinforced concrete bridges.

In reply to the above the speaker would point out that, as might be ascertained by any bridge designer who was willing to take the trouble, the gross effect on the cost of either steel or reinforced concrete bridge, obtained by reducing the impact from that given by the above formula to half that value, was of the order of 1% : uniformity and safety could therefore be assured, without sacrifice of economy, by the adoption of this formula.

In conclusion the speaker would like to draw attention to the above mentioned proposed Standard Specification for Road Bridges in India, which had been prepared and adopted by the Indian Roads Congress, and to express the hope that it would soon be adopted by the various provinces in place of the many different specifications which were in use.

The AUTHOR in replying said that he was extremely obliged to Mr. W. A. Radice for his appreciative criticism of his Paper, but it was interesting to note that Mr. D. S. Desai did not appear to share his views.

Mr. Radice mentioned that last year Mr. W. G. Turnbull of the Concrete Association of India was appointed by the Council of the Indian Roads Congress to make a report regarding impact on bridges. At that time Mr. Turnbull asked the Author to write a Paper on impact with special reference to Reinforced Concrete Bridges, and desired him to put forward a recommendation for estimating allowances for impact in relation to different types of Reinforced Concrete Bridges. In acceding to Mr. Turnbull's request the Author considered primarily the most suitable method for dealing with the subject, and came to the conclusion that figures would be most convincing.

Mr. Radice associated himself with the practical and economical men, whose chief consideration in the matter of construction was its monetary importance. Likewise, the Author, who had been attached to contractors' office for nearly 14 years, (four years in Germany and ten in India), and therefore, had to employ most of his time in problems of construction, naturally devoted himself to practical economics. It was hardly necessary to observe that this principle of economy in theory and practice must, in view of the present day keen market competition, be the especial concern of all engineers for the purpose of minimising the cost of any constructional work. The engineer, who was unable to foresee wastage in building materials and make the necessary provisions for this during the course of preparing estimates, placed himself at a decided disadvantage.

A contractor's engineer could not afford to add 10 to 20% to his estimate for the sake of unshaken "safety" in providing for impact, while on the other hand he must be so fully conversant with stress and strain in a structure as to be absolutely certain that no increase was required. It surpassed one's imagination to realise what an immense responsibility was entrusted to the designer from whom a profound knowledge of theory and practice was expected and demanded. Therefore, it was essential that an engineer should have a definite understanding of the most exact and accurate measurements, and a thoroughly clear idea of main and secondary stresses which occurred in each member of the construction.

Being convinced of the essentiality of these points, it was the Author's intention to write this Paper on impact explaining as briefly as possible the causes, nature and magnitude of the impact by an exact method mathematically expressed, but it was not his desire to make a personal display of his mathematical knowledge on impact before the Institution of Engineers.

This method when given effect to, should in turn assist the decision of the engineer in matters of bridge building with a view to improving his estimate and helping him to avoid blindly following the stereotyped building principles when the actual local causes of impact were known to him. An empirical formula could not help much in this respect.

As regards the empirical formula which had been put forward by the Roads Congress Committee, it was difficult at this stage to say how long this formula would be employed by the engineer after he had before him more information regarding the causes and reasons of impact on a bridge. The Author was aware that there were many who objected to this formula, and who did not agree to there being one formula applicable to various types of bridges—steel, wooden or masonry, fixed, demi-fixed or suspended. This objection was easily understandable, and the Author took the opportunity to show again mathematically the difference of the damping value on vibration of steel and concrete in different members, as vibration was one of the main factors causing additional deflection.

It is known to engineers, who are conversant with vibration problems in engineering that the damping factor of a steel beam is $e^{-0.5kt}$

where e = Naperian base 2,71,828

t = time

$k = R/M$

$\frac{R}{M} = \frac{dx}{dt}$ is a term corresponding to a force proportional to the first power of the velocity which when added

to $\frac{dx^2}{dt^2} + \frac{k}{M}$

will represent the case of free vibrations with friction.

M = Coefficient of mass.

R = Coefficient of frictional resistance.

The fundamental period of a free beam but fixed for translation and rotation is

$$T^2 = 3{\cdot}20 \cdot \frac{wl}{EI_c}$$

Therefore, if the subscripts c and s denote concrete and steel respectively, the ratio between the period will become

$$\frac{T^2c}{T^2s} = \frac{W_c E_s I_s}{W_s E_c I_c}$$

where W = Weight per Linear Foot

E_c = Elastic Modulus for Concrete

E_s = Elastic Modulus for Steel

I_s = Moment of Inertia for Steel

I_c = Moment of Inertia for Concrete.

For a uniformly loaded, rectangular free beam the Bending Moment at a distance x is $\frac{Wx^2}{2}$

Extreme fibre stress in compression is $S = \frac{BM}{I} \cdot \frac{d}{2}$

and $I = \frac{bd^3}{12} = \frac{2\,by^3}{3}$; $y = \frac{d}{2}$

and $y^3 = \left(\frac{3Wx^2}{4\,bs}\right)^{3/2}$

Substituting I_c, I_s, y^3c, y^3s, the equation becomes

$$\frac{T^2_c}{T^2_s} = \frac{E_s}{E_c}\left(\frac{W_s}{W_c}\right)^{\frac{1}{2}}\left(\frac{S_c}{S_s}\right)^{3/2};$$

as $M = \frac{k}{n^2}$ or $n^2 = \frac{(2\pi)^2}{T^2}$, where k is the coefficient of elasticity and may be replaced by Young's Modulus E. Therefore

$$k = \frac{(2\pi)^2 R}{T^2 E}, \text{ and}$$

$$\frac{T^2_c}{T^2_s} = \frac{E_s \; k_s \, R_c}{E_c \; k_c \, R_s} \text{ ; further equating,}$$

$$\frac{k_c}{k_s} = \frac{R_c}{R_s} \left(\frac{W_c}{W_s}\right)^{\frac{1}{2}} \left(\frac{S_s}{S_c}\right)^{3/2}$$

If we make $f_c = 700$ lbs. per sq. inch and
$f_s = 18{,}000$ lbs. per sq. inch and

$R_c = 7{,}270$, $R_s = 16{,}465$ as given by Suyehiro* and assuming that $b = 12''$ and d_s 12″ for steel beam, the equivalent depth of concrete beam etc., to carry the same load $d_c = 5{\cdot}07$

The weight per linear foot of each beam is
$W_s = 490$ lbs.
$W_c = 5{\cdot}09 \times 150 = 760$ lbs., and solving k_c
we get $k_c = 7 \cdot 1 \, k_s$

and the damping factor for R. C. beam will be $e^{-\frac{1}{2}(7{\cdot}1 k_s) t}$

against the damping factor for steel which is $e^{\frac{1}{2} kt}$

Comparing these two factors, it is obvious that reinforced concrete is far more effective than steel in damping vibration and the same impact will cause less additional deflection in R. C. than in Steel.

The analysis put forward by Mr. Radice showing the effect of the impact factor on the cost of bridges was indeed interesting. However, it was clear that the result thus obtained, taking an average of 16 different types of bridges, could but be general. It could be proved that the effect of 1% impact increased the superstructure cost of the bridge by 0·33%. This is exmplified by the following typical case.

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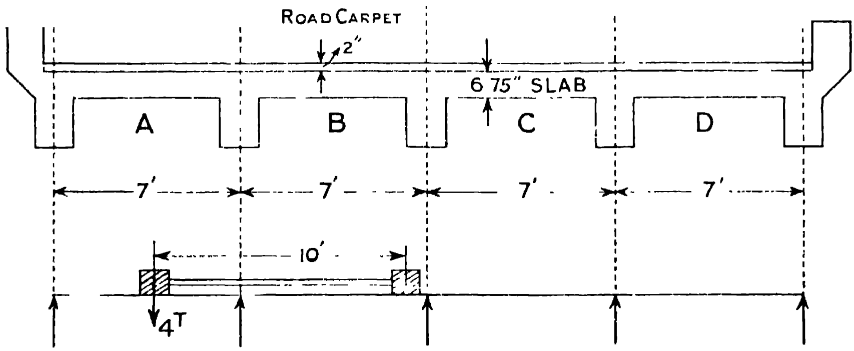
*Suyehiro : Engineering Seismology, Proc. Amer. Soc. Civil Eng. May 1932 and Jacob T. Greskoff: Dynamicks of Earthquake Resistant Structures.

EFFECT OF IMPACT ON R. C. SLAB (OF A. R. C. ROAD BRIDGE).



Firstly let the effect of impact on R. C. slab be considered :
Assume concrete roadway 2" thick

and R. C. slab = 6.75"

Then the dead load for roadway is 25·000 lbs.
for slab ,, 84·375 lbs.
Total 109·375 lbs. say 110 lbs.

B. M. due to D. L. in spans A. and D. :—
$0·079 \times 110 \times 7^2 = 425$ ft. lbs.

Load of wheels of a 10-ton steam roller—4.00 tons approximately (assumed for simplicity in calculations)

B. M. due to L.L. without impact (*a*) $\frac{4·00 \times 2·7 \times 2,240}{12}$

= 2,015 ft. lbs. in x-x direction.

(*b*) $\frac{4·00 \times 2·1 \times 2,240}{12}$

= 1,570 ft. lbs. in y-y direction.

If 30% impact be considered, the bending moment will increase from 2,015 ft. lbs. to 2,620 ft. lbs. in x-x direction.

Therefore, the total B. M. is as follows :—

(*a*) without impact = 2,015 + 425 = 2,440 ft. lbs.

(*b*) with 30% impact = 2,620 + 425 = 3,045 ft. lbs.

Assume $f_c = 600$ lbs./in²

and $f_s = 16500$ lbs./in².

Therefore, the effective depth of the slab = h—a.

$$= 0{\cdot}1023 \sqrt{\frac{Bm \times 12}{12}}$$

$$= 0{\cdot}1023 \times \sqrt{\frac{2440 \times 12}{12}}$$

$$= 5{\cdot}05''.$$

Also the effective depth due to 30% impact $= 0{\cdot}1023 \times \sqrt{3045}$
$= 5{\cdot}65''$.

Therefore, the total depth of the slab will have to be increased from 6·75″ to $\{5{\cdot}65'' + (6{\cdot}75'' - 5{\cdot}05'')\} = 7{\cdot}35''$. Thus it is seen that a new dead load is born, which is equivalent to $\frac{425}{110} \times 119 = 460$ lbs. so that the B. M. becomes equal to $2620 \times 460 = 3080$ ft. lbs.

Hence the increase in the weight per square foot of the slab = 9 lbs. which is equivalent to an increase of 12% due to 30% impact, or to an increase of 0·4% due to 1% impact.

Similarly, the total cost will be increased proportionately.

Regarding the steel, the requirements will be as follows :—

(1) without impact :—$A_s = 0{\cdot}000739 \times \sqrt{Bm} \times b$

$= 0{\cdot}000739 \times \sqrt{2440 \times 12 \times 12}$

$= 0{\cdot}438$ sq.in. in x—x direction

and $A_s = \frac{9}{8} \times \frac{1995 \times 12}{16500 \times 6{\cdot}38}$

$= 0{\cdot}256$ sq. in. in y — y direction.

(2) with 30% impact :—$A_s = 0{\cdot}000739 \times \sqrt{3080} \times 12 \times 12$

$= 0{\cdot}492$ sq.in. in x—x direction

and $A_s = \frac{9}{8} \times \frac{1995 \times 12}{16500 \times 6{\cdot}2}$

$= 0{\cdot}263$ sq.in. in y—y direction.

Therefore, the total amount of steel required without impact $= 0{\cdot}438 + 0{\cdot}256 = 0{\cdot}694$ sq. in.

And the total amount of steel required with 30% impact :—

$$0{\cdot}492+0{\cdot}263=0{\cdot}755 \text{ sq. in.}$$

Therefore, in allowing 30% for impact the percentage increase in the amount of steel is 8·9%.

Similarly the cost will be increased by the same percentage, *i.e.*, due to 1% impact there will be a corresponding increase in the cost :— $\frac{8{\cdot}9}{30} = 0{\cdot}297\%$ *i.e.* 0·3%.

Hence the total increase in the cost due to 1% impact :—

$$\frac{0{\cdot}4+0{\cdot}3}{2} = \frac{0{\cdot}7\%}{2} = 0{\cdot}35\%.$$

Secondly, let us consider a freely supported beam of h = 5 feet span = 34 feet and width = 12 inches.

Weight of beam = $5 \times 150 \times 1 = 750$ lbs.

Weight of slab without impact = 110×7 = 770 lbs.

Total 1520 lbs.

$$\text{Bending moment} = \frac{1520 \times 34 \times 34}{8} = 219700 \text{ ft. lbs.}$$

$$\text{B. M. due to live load} = \frac{4 \times 2240 \times 34}{4} = 76150 \text{ ft. lbs.}$$

Total B. M. = 295850 ft. lbs.

Therefore, the effective depth of the beam :—

$h - a = 0{\cdot}1023 \times \sqrt{295850} = 55{\cdot}6$ inches

$a = 4{\cdot}4$ inches, $h = 60$ inches = 5 feet.

Thus the steel required :— $0{\cdot}000739 \times \sqrt{295850} \times 12 \quad 12$

$= 4{\cdot}82$ sq. inches.

And now take the same case with 30% impact :—

Dead load of slab = 119×7 = 833 lbs.

Dead load of beam = $5{\cdot}33 \times 150$ = 800 lbs.

1633 lbs.

$$\text{B. M. due to dead load} = \frac{1633 \times 34 \times 34}{8} = 236000 \text{ ft. lbs.}$$

B. M. due to live load with 30% impact =76150 feet lbs. + 30% × 98995 feet lbs. = 334995 feet lbs.

The effective depth of the beam = $h-a=0{\cdot}1023\times\sqrt{334995}$ $=59{\cdot}2$ inches.

$\therefore$ $h=59{\cdot}2$ inches + 4·8 inches = 64 inches = 5·33 feet. Thus the steel required $=0{\cdot}000739\times\sqrt{334995}\times12\times12=5{\cdot}13$ sq. in. Hence, the weight of concrete in the beam is increased by 6·6% and that of steel by 6·5% due to 30% impact which is equivalent to 0·22% and 0·217% respectively due to 1% impact. Therefore, the total cost of the slab and beam only is increased by (0·35 + 0·22 + 0·217) 1·3 = 0·26% due 1% impact. Further calculations from a monetary point of view give the following results :—

SLAB. Concrete :

$$\left\{\begin{array}{ll}\text{without impact :} & \dfrac{6{\cdot}75''}{12}\times7'\times28'\times\dfrac{150}{2240}\times\text{Rs. }40=\text{Rs. }295/\text{-}\\[2ex] \text{with 30\% impact :} & \dfrac{7{\cdot}35}{12}\times7'\times28'\times\dfrac{150}{2240}\times\text{Rs. }40=\text{Rs.}322/\text{-}\end{array}\right\}$$

an increase of 8·9%

Steel :

$$\left\{\begin{array}{ll}\text{without impact :} & 0{\cdot}694\times4\times\dfrac{28}{2240}\times7\times\text{Rs. }300=\text{Rs. }73/\text{-}\\[2ex] \text{with 30\% impact :} & 0{\cdot}755\times4\times\dfrac{28}{2240}\times7\times\text{Rs. }300=\text{Rs. }79/\text{-}\end{array}\right\}$$

an increase of 8·7%

BEAM. Concrete :

$$\left\{\begin{array}{ll}\text{without impact :} & \dfrac{5\times5\times1\times34\times150}{2240}\times\text{Rs. }40=\text{Rs. }2280/\text{-}\\[2ex] \text{with 30\% impact :} & \dfrac{5\times5{\cdot}33\times1\times34\times150}{2240}\times\text{Rs.}40=\text{Rs. }2430\end{array}\right\}$$

an increase of 6·6%

Steel :

$$\left\{\begin{array}{ll}\text{without impact :} & \dfrac{5\times48{\cdot}2\times34\times5}{2240}\times\text{Rs. }300=\text{Rs. }550/\text{-}\\[2ex] \text{with 30\% impact :} & \dfrac{4\times5{\cdot}13\times34\times5}{2240}\times\text{Rs. }300=\text{Rs. }585/\text{-}\end{array}\right\}$$

an increase of 6·5%

Thus the total increase due to 30% impact is 7·7% *i.e.* for every 1% impact there is an additional increase of 0·26% in the total cost of beams and slab only.

When the effects caused by impact on all other members of the bridge structure *viz.*, cross beams, bed plates, etc. are scrutinized, the total cost of the whole bridge superstructure is increased by 0·33% due to 1% impact on the bridge.

The total cost of 16 different types of bridges as stated by Mr. Radice amounted to Rs. 10,78,550. Owing to every 1% impact on the bridges the total cost would be increased by Rs. 3,548/-. Thus if 30% impact on the bridges be considered, the total cost of the bridges was increased by Rs. 1,06,440/- which was an appreciably large figure. The question of allowances for impact for different widths could best be dealt with by considering the distribution of moments denoted by the formula $1 - c \dfrac{lx^2.ly^2}{lx^4 + ly^4}$ in both the x—x and y—y directions. A special allowance was generally made in the case of road bridges but the Author did not see any justification for this, although railway bridge designers justifiably did make a special allowance for impact "I" in the following manner :—

For single track span, "I" $= \dfrac{65}{45+L}$

(in the case of 5′—6″ and 3·28′ gauges)

For double track span, "I" $= 0·72 \times \dfrac{65}{45+L}$

These formulae are applicable when the span ranges up to 80 ft. provided the ratio of span to depth does not exceed 12.

For broad gauge Railway Bridge, "I" $= \dfrac{V}{60} \times \dfrac{65}{45+L}$

For metre gauge Railway Bridge "I" $= \dfrac{V}{45} \times \dfrac{65}{45+L}$

where v=speed in miles per hour and L=the loaded length of span in feet.

And also for 2′-6″ and 2′ gauge railway bridge "I" $= \dfrac{300}{300+L}$.

These different formulae applicable for various types of railway bridges pointed to the fact that the rails surmounted to the sleepers, fixed on to the girders, acted like stiffeners and the amount of stiffening depended upon the position and number of rails. This had been proved experimentally and could easily be corroborated mathematically. However, there was absolutely no reason for making a special allowance for impact on road bridges because in that case the moment distribution was the only factor concerned which decreased the additional deflection caused by the impact. There was, however, some justification for making an allowance for fixed or continuous beams and slabs in which instance no allowance was provided by the recommended formulae $\frac{1}{2}.\ \dfrac{65}{45+L}\ \dfrac{(n+1)}{2}$.

The original railway bridge formula $\frac{1}{2}.\ \dfrac{65}{45+L}$ was meant for freely supported girder bridges. As a matter of fact, most railway bridges built in India were constructed of freely supported girders but the majority of R. C. road bridges were comprised of continuous or fixed beams.

The Author considered that the railway authorities had every right to accept a simple practical formula for the design of railway bridges, since most of the factors which were influenced by impact were all known and more or less uniform for all types of railway bridges, e. g., the maximum speed of locomotive, the quality and section of the rails and sleepers, and the distance between the rails and sleepers. There was only one factor L to be determined in order to ascertain the impact, but this was not the case where road bridges were concerned. However, the decision to diminish allowances made for impact had to be left entirely to the engineer, but before long he would know the factors which were influenced by impact, and consequently he would be prepared to expend a little more for a reinforced concrete carpet on a road bridge in preference to utilising a Water-bound Macadam surface or a stone-set paving. Anyway, the cost of the carpet when compared to the total cost of the bridge was negligible.

Incidentally, Mr. Radice had mentioned two standard live loadings for two kinds of bridges recommended by the Indian Roads Congress for adoption throughout India. The Indian Standard Loading was stipulated as follows :—

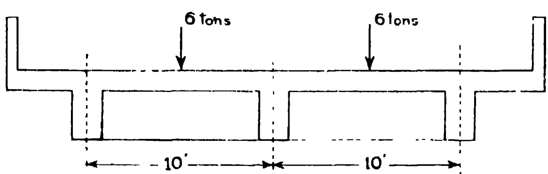
"0·34 ton per linear foot of each traffic lane width of 10 feet plus a knife-edge load of 6 tons for computing bending moments or a load of 9 tons for computing shears with the limitation that for computing bending moments, the total distributed load on loaded lengths of 20 feet and under shall never be less than 6·8 tons per lane of traffic over the whole loaded length."

This rule applied only in the case of the Light Indian Standard Loading; the formulation for the heavy loading being similar; the figures of course being relatively increased. From the point of view of accuracy, which was essential in bridge designing, this formulation was an unfortunate one in that it could be and was interpreted in various ways by different engineers.

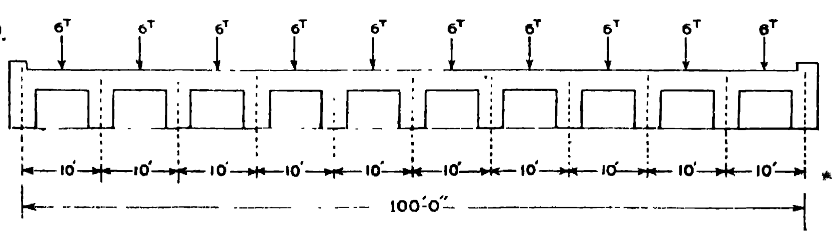
It had been the experience of the Author's office and other offices as well, that this formulation had created much confusion and controversy, in so far as the engineers had found it difficult to arrive at its exact meaning.

Was it meant to convey a knife load of 6 tons placed in centre of slabs in the middle of the cross beams or longitudinal beams as demonstrated in the following sketches below?

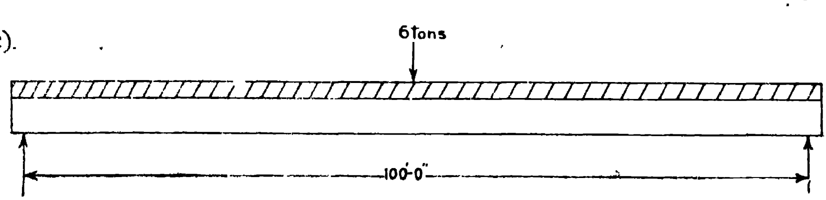
(a).



(b).

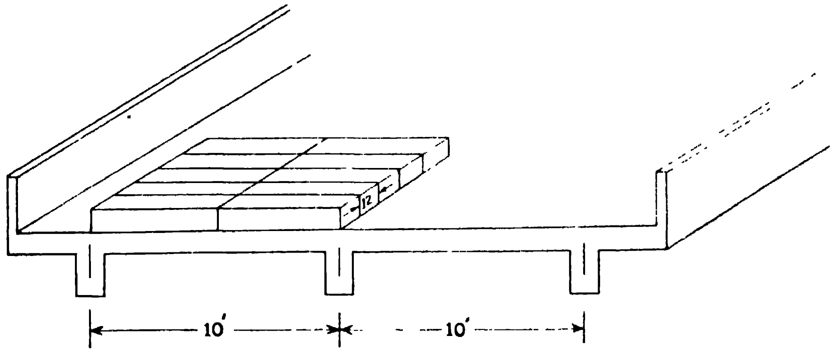


(c).



or

(2) 0·34 ton per linear foot of each traffic lane width of 10 ft. should be as indicated below—



that is, in other words, a load of 76·16 distributed over every square foot of the traffic lane?

As regards the knife-edge load of 9 tons for computing shears, it surpasses one's imagination to conceive how this should be treated in practice. It was a matter for conjecture whether the load of 9 tons should be placed at the ends where a maximum shear could be expected or located as per sketches a, b, or c. Regarding the practicability of using the knife-edge loading in the designing of girders, beams and stringers, it was left entirely to the imaginative brain of the designer to form his own idea.

The Ministry of Transport, years ago, issued a similar rule for using knife-edge loadings in the designs. In order to make it easily conceivable and applicable in practice, an equivalent loading curve had been drawn up by C. S. Chettoe, B. Sc., A.M. Inst. C. E., and Haddon C. Adams, M.C., M.A., A.M. Inst. C. E., who had written a comprehensive Paper on this subject with numerous examples of application. It was, however, unfortunate that an abstract or non-existent form of loading should be adopted in designing bridges over which rolling loads of exact dimensions would have to be carried. The Author had been asked several times about the meaning of the term "knife load." A knife load, the Author understood, was a load which created great bending moment and shear causing thereby the collapse of the load or the loaded subject. Further, when impact had to be applied, together with a knife-edge load, it

would act like a bullet. Consequently, the Author was of the opinion that, when a knife-edge load could not be used for the purpose of testing a bridge, then a proper substitute, for example, a lorry, steam roller, locomotive or some other rolling load, had to be found to suit all the existing conditions, but this had to so satisfy these conditions as to produce an equivalent bending moment of 6 tons knife-edge load and simultaneously an equivalent shear with 9 tons knife-edge load. However, to comply with all these necessary conditions, it would be difficult to find a suitable vehicle. The Roads Congress might be asked to ascertain a solution to this problem.

In reply to Mr. Radice's comments the Author hoped that he had answered most of the questions raised by his colleagues. However, one of Mr. A. Vasudevan's remarks about dynamical stresses causing disintegration of the ingredients (which is observed more in R. C. than in steel) still called for attention, and the Author could reply to it in quoting an instance from his own personal experience.

In 1917 the Author, while in Kopenhagen as a Marine Engineer, built one 3000-ton R. C. Diesel Motor-ship which collided with a 16,000-ton German steel steamer near Kiel. As a result of this dynamical encounter there was a big hole in the side-board of the R. C. ship, which was about 16 ft. square in size, and was repaired with an R.C. patch in the course of a day, while the German steamer had to go to the dry dock for 5½ months for repair.

Mr. R. N. Joshi's doubts about the usefulness of the Author's formula were due to the fact that on page 93, while dealing with vibrations, the amplitude was not mentioned, but it had possibly escaped Mr. Joshi's notice that the Author dealt with this question directly and indirectly on another page.

The Author did not agree with the remarks as regards steel structure giving more time of warning before collapsing, since he was able to cite a case where a badly built R.C. bridge, which it was predicted would collapse three years ago, only did so this year. A three years' warning was a sufficiently long period.

Mr. Desai mentioned the case of the Forth Bridge in Scotland and stated that it carried a much heavier live load than that for which it was designed, but he did not specify how many times heavier a load it carried. The Forth Bridge, which was made up of 60,000 tons of steel, had a double line of rails and was carrying 2·4 tons per foot, the total span being 8,295 ft. The bridge was designed to carry this load and this was adhered to. As for maintenance the Forth Birdge was continually in repairs and was perpetually painted and re-riveted. Regarding the statement of the deterioration of steel bridges, as per diagram No. 4, it had been taken by the Author from the statistics of several countries. The Author had, in his short time in India, replaced many steel bridges (about 12 in eight years). In Calcutta alone he had opportunities of replacing six, *viz.*, Alipore, Narcaldanga, Beliaghatta, Chitpur, Chandmari, and Manicktolla Bridges. It might be added here that the E.I. Railway alone were disposing of several thousands of tons of scrap steel bridges, *viz.*, Sai Bridge and others.

In conclusion, the Author was very much indebted to the Chairman of the various centres of the Institution of Engineers and also to the members for patiently going through his Paper and discussing it with keen interest.

CONCRETE ROADS AND THE BULLOCK CART

BY

T. R. S. KYNNERSLEY, M.C., A.C.G.I., Member.

It is generally recognised that iron-tyred bullock cart traffic causes more damage to roads than any other class of traffic, and one of the most difficult problems road authorities in this country have to contend with is to provide road surfaces capable of withstanding heavy iron-tyred traffic. The time-honoured water bound macadam road, of which there are thousands of miles in India, no longer serves the purpose economically as it rapidly disintegrates under the bullock cart combined with fast moving lorry and bus traffic, which now prevails on almost all roads. An urgent need has therefore been felt by all Road Engineers during the last decade for some better and more lasting surface to avoid unjustifiably large sums spent on ceaseless maintenance.

A durable wearing surface can be achieved by means of a suitable "binder" which will bind the stones and hold them firmly in position, preventing their displacement by impact shocks. The quest for such a binding medium led to research many years ago in America and other countries, and as a result Portland Cement was found to be one of the most suitable binders having definite advantages over others. This is also borne out by their actual experience with the construction of concrete roads over several years and the following figures of mileage of improved roads with superior surfaces constructed in U. S. A. at the end of 1936 will be of interest.

Portland Cement Concrete ..	87,865
Bituminous Concrete ..	11,583
Bituminous Macadam ..	16,555
Brick and other block types ..	3,386
Low-cost Bituminous mix ..	45,555

Cement concrete roads were first introduced in India in 1920 and several stretches of this type have since been laid in various parts of the country. There are in existence some lengths of these roads over 10 years old, carrying very heavy traffic, specially iron-tyred, which are in excellent condition even to-day. Their value as a good lasting surface without much maintenance for Indian traffic and climatic conditions has been proved beyond any doubt, as will be evidenced from the reports and opinions of many eminent Engineers who have had experience with this type of construction. As an example an extract from the report of the Chief Engineer of Hyderabad, Deccan, who has constructed a large mileage of concrete roads, is given below.

"In conclusion the cement concrete roads in Hyderabad have proved a great success, and can be the only useful surface for all cities in general where there is heavy traffic and particularly for the bullock carts with iron-tyred wheels which are the principal vehicles for the transport of goods in India for generations past and will probably remain so for generations to come for the simple reason that power used for agriculture in India is invariably derived from bullocks."

In the past, concrete roads with heavy Sections—6" to 8" thick slabs—were laid and consequently their very heavy initial cost militated against their greater adoption except for very heavily trafficked roads. In the ultimate cost, however, it has proved to be the cheapest compared with other types of road surfaces under similar conditions. But during recent years of adverse economic conditions, efforts have continually been made to cheapen the cost of concrete roads by various means. And at present, with fuller knowledge of the many factors affecting the design, and the actual experience gained from construction, it has been made possible to design economically a concrete road slab from 2" to any required thickness to suit any particular conditions of traffic and subgrade. In addition, material reduction in the price of cement, now, has also lowered the cost of concrete roads.

The attempts to obtain a concrete wearing surface at low cost have also led to the evolution of other types of cement road construction such as Cement Macadam, Bonded Concrete and Rolled Concrete. The accompanying table gives the

suggested designs of concrete road surfaces for various traffic intensities together with particulars of approximate costs per 100 sq. ft.

SUGGESTED ROAD CATEGORIES.

Category	Intensity of Traffic.	Suggested Treatment.	*Cost per 100 sq. ft.
I.	Carrying mixed traffic, under 20 tons per ft. width per day.	Tar or bitumen.	
II.	Carrying mixed traffic, 20 to 35 tons per foot width per day	Tar or bitumen.	
III.	Carrying mixed traffic, 35 to 50 tons per ft. width per day.	Bonded Concrete 2" thick, suitably reinforced.	Rupees 16
IV.	Carrying mixed traffic, 50 to 100 tons per ft. width per day.	Concrete 6"—4"—6"	Rupees 31/6
V.	Carrying mixed traffic, 100 to 150 tons per foot width per day.	Concrete 7"—5"—7"	Rupees 37/6
VI.	Carrying mixed traffic, 150 tons and over per foot width per day.	Concrete 9"—6"—9"	Rupees 44/6

*The above costs are based on the price of cement at Rs. 40/- per ton at site. Coarse Aggregate Rs. 18/- per 100 c. ft. Sand Rs. 10/- 100 c. ft. No overhead charges or contractors profits are included.

The all-concrete road has many advantages, combining as it does the foundation and wearing surface. It is economical to the taxpayer, homogeneous, non-slippery and costs little in maintenance if properly laid. Its construction is quite simple and consists in laying properly mixed concrete of correct proportions—normally 1 : 2 : 4—on the prepared subgrade to the designed section between forms, and is tamped and finished to

the required grade and camber. The concrete slab is laid in sections of about 35 feet long and of a width less than 15 feet with expansion or plain transverse construction joints according as the method of construction adopted is continuous strip or alternate bay system. Whenever the width of the roadway exceeds 15 feet, it is divided into suitable widths with plain butt longitudinal joints. Dowel bars are put across transverse expansion joints to prevent unequal heaving and to transmit loads from one slab to the next.

Concrete roads are generally of plain concrete as under normal conditions reinforcement is not necessary. However, in especial cases when the road slab is laid on a subgrade (such as made-up ground) where unequal settlement is feared or thin slabs are used which are liable to cracking, some reinforcement is provided to hold together any cracks that form whether due to loads or temperature.

It has been definitely proved by practical tests that the wear on concrete roads is negligible over a long period; about one inch in 20 years. Obviously, if a thin wearing surface of concrete could be efficiently laid on a good foundation, it should provide a very economical solution for thousands of miles of old well-consolidated water bound macadam roads in India, specially district and provincial roads, which do not generally carry very heavy traffic. With this end in view, the author carried out several experiments in Bombay in 1933 with thin $1\frac{1}{2}''$ concrete slabs bonded to the existing macadam base with different types of light mesh reinforcements. The behaviour of these experimental lengths was carefully watched and conclusions drawn as to the most suitable reinforcement and other details of construction. The results obtained were very satisfactory and a proper specification was drawn up and an improved technique of construction developed. These experiments resulted in further trial lengths being laid in various parts of the country and their performance has been so satisfactory that the P. W. D. of the United Provinces have adopted this as a treatment for certain district roads carrying light bullock cart traffic.

This type of construction to which the name of "Bonded Concrete" has been given consists in laying a thin layer of concrete of 1 : 3 : 4 proportions over thoroughly wire-brushed

and cleaned waterbound macadam road with 2" mesh wire netting No. 16 gauge or other suitable steel fabric fixed in position so that it is at least 1" below the finished concrete surface. Prior to laying the concrete a neat cement grout is thoroughly brushed into the existing metal to bond the new crust with the old foundation. In other respects the construction is similar to the ordinary concrete road excepting that expansion joints are provided at the end of a day's work, with "dummy" joints inserted at about 35 feet intervals.

Of the other cheaper types of concrete roads, Cement Macadam has been adopted in England, Germany and America with considerable success. It has also been tried out in several places in India but with very indifferent results. This is due to its rather unscientific nature where the success or failure of the construction largely depends on the skill of the labour employed on the job in following the proper procedure. There are some lengths of this type in Vellore, Nagpur, Lucknow, etc. over 7 years old which are giving excellent service even to-day.

The process of constructing Cement Macadam roads is very similar to that of Water bound Macadam and was evolved mainly to obtain a cheaper cement road surface and also to adapt the labour and plant of road building organizations which have been accustomed to the latter construction. A $2\frac{1}{4}''$ layer of broken stone is first laid over the prepared subgrade and lightly rolled with a 10 ton road roller. Next a $1\frac{1}{2}''$ layer of dry mixture comprising 1 part of cement and 2 parts of sand, is evenly spread over the surface. On this dry mortar bed another $2\frac{1}{4}''$ layer of broken stone is laid to proper grade and camber, and the required quantity of water is uniformly sprinkled on the section in front of the roller before rolling is commenced. Rolling is done preferably with a tandem roller and is continued until the mortar works up to the surface. Any depressions and inequalities are removed by sprinkling on them small chips of stone and the surface is finished after the rolling is completed with screed or hand roller.

The latest development in low cost concrete roads, which is also an improvement on the above type, is the roller consolidated concrete road or "Rolled Concrete." This construction was first evolved in Australia and during a comparatively

short period it has met with considerable success. The general idea of this type is to use very lean mixes of concrete (with high strength mortar and relatively low water-cement ratio) mechanically consolidated by a heavy road roller. The design is based on the principle that the voids in coarse aggregate of even grading between 1½" to 2½" are greatly reduced by compaction in rolling; in consequence, roller consolidated concrete requires much less mortar than that placed in the usual manner. An average sample of loose coarse aggregate contains about 50% voids and as in water bound macadam construction a 4½" layer of road metal is consolidated by a roller to about 3" thickness, the void percentage in the compacted aggregate is reduced by about 33%. It should be logical therefore that in the roller consolidated concrete, the mortar content can be as low as 17% as compared to 50% in the normal 1 : 2 : 4 concrete to obtain a dense mix. However, the actual quantity of mortar will vary with the grading of coarse aggregate used, as for the same voids the smaller the size of metal the more mortar is required to cover each piece of stone with a thin film of mortar for purposes of binding them together.

Working on this principle, experiments have been carried out in Australia and other countries with various lean proportions of concrete—1 : 2 : 8 to 1 : 2½ : 12—and the results obtained have been very satisfactory. This type of construction was in the first instance adopted for constructing bases only, but with improved technique of construction some recent work is reported to possess riding qualities as good as the bulk of normally constructed all-concrete roads. There appears to be a very great scope for this type of road in India and its adoption will greatly depend on the first few trial lengths carried out here.

Briefly described, the construction consists of laying mechanically mixed concrete of specified proportions and consistency on the prepared subgrade between forms, in a layer about 25% to 33% in excess of the designed thickness of the finished road. The concrete is placed roughly by hand to proper grade and camber and is then rolled with a 10 ton road roller till the whole section is thoroughly consolidated. Any rough spots and inequalities are filled in with rich concrete (1 : 2 : 3½ mix containing small aggregate ¾" to ¼") and the

surface finally finished with a tamper and hand floats. Expansion joints are provided at about 100 ft. intervals with dummy joints at every 33 ft. approx. All other details follow the normal concrete road construction.

During the last three years still another form of low cost cement road is being developed in America, which may be simply described as the cement-hardened soil or technically "Stabilized Soil-Cement" road. Fundamentally, the process consists of mixing dry cement with the natural road soil, pulverising it, moistening it, then consolidating it to a dense and impervious mass, finally producing a smooth surface with the roller. Extensive investigations on this subject of soil stabilization are being carried out both in the field and the laboratory and the results will be watched with great interest by all road engineers, as it promises an economical means of improving unstable subgrades for highways, and the vast mileage of rural roads.

Brief specifications for the various types of concrete roads have been given above but a detailed procedure discussing the various operations, and the latest methods adopted in the construction of an all-concrete road may be of interest.

Foundation.—For a concrete road the foundation may consist either of natural soil subgrade or an artificial base such as an existing water bound macadam road, but it is most important that the subgrade or the base on which the concrete is placed should support the road slab uniformly to prevent its cracking. The foundation should therefore be constructed to have as nearly as practicable, an even-bearing power throughout. It should be formed by excavating and grading the existing surface to proper section and alignment and then rolling it with an 8-10 ton roller until it is uniformly compacted. It should also be properly drained.

Forms.—The longitudinal and transverse forms (shown in the appendix) which are either of wood or steel should be rigidly fixed by means of iron spikes on the prepared subgrade to prevent their displacement during concreting. They should be set to exact grade and alignment at least 100 ft. in advance of the point of depositing concrete. They should be thoroughly oiled before concrete is placed against them and should not be removed until 24 hours have elapsed.

Insulation.—Some kind of insulation is necessary between the concrete road slab and the subgrade to facilitate the movement of the slab due to expansion and contraction. Until recently an insulation layer of sand was used for this purpose. But it has been found that it has certain disadvantages in that the sand absorbs cement water, from the bottom layer of the concrete slab, thereby causing honeycombing and weakening it and also does not allow free movement. To overcome this, waterproof paper has been used with considerable success and is recommended for use.

Joints.—Joints are necessary in a concrete road to provide for the expansion and contraction of the slab due to changes in temperature and moisture content. Their spacing is primarily a matter of controlling cracks. These are therefore designed and spaced so as to permit the slab to expand, contract, warp and overcome the friction between the subgrade without setting up tensile stresses in it exceeding the strength of concrete and thus preventing the occurrence of any intermediate cracks. Experience indicates that joints to control warping should be placed at intervals of about 10′ to 15′, while for expansion and contraction suitable spacing should be 30′ to 35′ for Indian conditions.

Edge Thickening and Dowelling.—Since a free edge is a structurally weak spot in a slab of uniform thickness, it is necessary to strengthen the joint edges by thickening the slab at the point or by using dowel bars for transferring a part of the applied load across the joint to the adjacent slab. It is usual practice here to thicken the longitudinal edges, but as it is not feasible to consolidate the subgrade to admit of thickened edges for the transverse joints it is found convenient to use dowel bars. These are usually $\frac{3}{4}''$ dia. mild steel bars 4 ft. long and placed in the centre of the slab at 2 ft. intervals.

In both expansion and contraction joints, one end of the dowel should be bonded and the other end free to slide. This is effected by painting and covering the free length of the dowel with a stiff paper tubing. Some space should also be left at the free end for movement, which may be formed by placing a lump of asphalt at the end of the paper sleeve. In a construction joint both the ends should be bonded. It is extremely important that dowel bars should be carefully placed in position

during concreting to prevent severe damage at every point. To keep them in their correct position it is good practice to wire the ends of the dowels so as to keep them parallel to the faces of the slabs and also support them on some sort of chairs. Various types of patent dowels have been tried in America, some of which have been found to be very satisfactory.

Longitudinal Joints.—The general practice in this country is to have these as plain butt construction joints with thickened edges, making each strip separate. If the pavement is very wide, provision must be made for lateral expansion and contraction. When a thickened edge is to be avoided, steel dowels ½″ dia., 4 ft. long, placed at 5 ft. centres are provided to transfer the load across the joint. With thick slabs, 8″ or over, a tongue and groove joint with or without dowels may be used as this has proved to be very efficient in America and England.

Transverse Joints.—Transverse joints should never be staggered unless adjacent slabs are completely separated by longitudinal joints with expansion joint material so that independent longitudinal movement is assured. In the past joints inclined at 60°—75° to the longitudinal axis of the road have been used by some engineers, but recent practice favours right-angled joints, which are commonly adopted in this country.

Very great care should be taken during construction to have the adjacent slabs at the joints in one level. High joints produce a rough-riding surface and constitute a source of annoyance to the motorist. These are frequently found with expansion joint design where the filler protrudes over the slab and should therefore be very carefully finished with a split-float and also checked by means of a long straight-edge notched in the centre (shown in the appendix). To prevent spalling of concrete at the joints, all edges of the slab should be rounded off with a ⅜″ radius edging tool.

(a) *Expansion Joints.*—As these are generally placed at 35 feet intervals, ⅜″ gap is provided between adjacent slabs which should be filled in with expansion joint material. These joints are either provided with premoulded fillers which are used during concreting or they are filled in with a mixture of hot bitumen and fine sand after the concrete has set.

Some of the bituminous fillers have been found to be very inefficient and they are squeezed out when the slabs expand.

The exuded material not only forms an objectional ridge, but the depleted filler permits moisture to get through to the sub-grade when the slabs shrink. Moreover, dirt and sand particles get into the joint, forming an unyielding filler that kills the effectiveness of the joint. To avoid this trouble some excellent flexible metal joints have been devised, which are quite satisfactory, but their use has been limited owing to their high cost. Recently some novel fillers composed of rubber, cork, etc. have been developed, which are reported to meet the requirements of a good filler.

A ½″ expansion joint should be left round all manhole covers, poles or other structures which protrude through the pavement.

(b) *Contraction Joints.*—These are plain butt joints provided at about 35 ft. intervals with or without dowel bars. In India these are generally constructed without dowel bars, but experience of other countries indicates that dowelled joints are the most efficient. To avoid the use of dowel bars, concrete sleepers 18″ wide by 9″ deep under the joints have been tried in England but with not very satisfactory results. Up-to-date practice, however, recommends the use of properly designed expansion joints instead of plain butt contraction joints.

(c) *Dummy Joints.*—These are weakened planes made by cutting through the top 2 or 3 inches of the slab. The cutting tool usually consists of a "T" fixed to the bottom of a long plank provided with handles (shown in the appendix).

(d) *Construction Joints.*—These should be formed whenever it is necessary to stop concreting for more than 30 minutes due to the breakdown of the mixer or any other cause. They should be provided with dowel bars.

Camber.—Very little slope or camber is required on a concrete pavement for proper drainage of water. This is a great advantage as the traffic which generally keeps to the centre of the roads with steep cambers can very safely and comfortably keep to their proper sides on concrete roads. The normal camber provided for concrete roads is 1 inch in 5 ft. The profile of the pavement may either be a circular or a parabolic

curve, but the latter is easier to design and hence generally adopted.

Reinforcement.—Normally, reinforcement is not necessary in concrete roads. However, whenever it is used, its function usually is not so much to increase the load-carrying capacity of the concrete pavement, but to resist small stresses due to slight uneven settlement of the subgrades or variations in temperature, and hold together any cracks that may form, thereby preventing further disintegration. It generally consists of a steel fabric or mild steel bars formed into a mat.

Materials for Concrete and Proportioning.—The materials comprise Portland Cement, which is of a standard quality and aggregates. Both coarse and fine aggregates should consist of hard, tough, durable and uncoated particles free from any flaky or deleterious matter, and most important of all, they should be perfectly clean.

Broken stone should be well graded from the maximum size, depending on the thickness of the slab, to $\frac{1}{4}''$ and the sand from $\frac{1}{4}''$ to 100 mesh seive in such a way that each has the least possible void percentage. The strength of the concrete is based on the water-cement ratio and the proportion of stone and sand is fixed to secure the desired workability and the densest possible mix. Proper control in the moisture content of the aggregates will ensure concrete of uniform quality. Commonly, concrete proportion of approximately 1 part of cement, 2 parts of sand and 4 parts of aggregates with 6 gallons of water per bag (inclusive of moisture in aggregates) are used in this country. Concrete should be mixed in whole bag batches.

Methods of Construction.—The concrete road slabs can be laid either in the alternative bay system or by strip method, but the latter has certain merits and is standard practice in Europe and America. In alternative bay system every other bay is first laid and after four days when most of the shrinkage of concrete has taken place the intermediate bays are filled in. The joints are plain butt contraction joints with or without dowel bars. In the strip method, the bays are laid successively

by placing premoulded bituminous filler between consecutive slabs to provide for contraction and expansion of concrete. The transverse joints are designed as expansion joints with dowel bars.

Mixing Concrete.—As far as possible concrete should be mixed in a suitable mechanical mixer and the time of mixing should be at least 2 minutes.

It is generally difficult to exercise proper control on the cleanliness of aggregates, and proportioning and mixing of concrete on the job site. To overcome this, ready-made concrete service has been recently introduced in America and Europe with remarkable success. Mixed concrete is delivered at the site of work by means of truck mixers or agitators from a central plant where everything is scientifically controlled. In the case of a truck mixer, properly measured quantities of cement, water and clean graded aggregates are carried on the truck and concrete is thoroughly mixed in the mixer while in transit to destination, and is deposited on the site by means of chutes. In the truck agitators, concrete which is already suitably mixed at the plant is taken in the agitator and during transit to destination, concrete is kept slowly mixed so that it is discharged at the site without segregation.

Placing Concrete.—Immediately before placing concrete on the subgrade it should be checked by means of a scratch template (shown in the appendix) and any unevenness detected by the template should be removed. The insulation paper should then be spread on the surface and concrete deposited on it to the required depth and for the entire width of the slab between forms in a continuous operation. While being placed, concrete should be vigorously sliced and spaded especially against the forms, to prevent honeycombing.

When the concrete is placed in two layers as in two course construction or to permit the use of steel reinforcement the first layer should be roughly struck off with a screed at the proper level and the second layer placed within 15 minutes of the laying of the first.

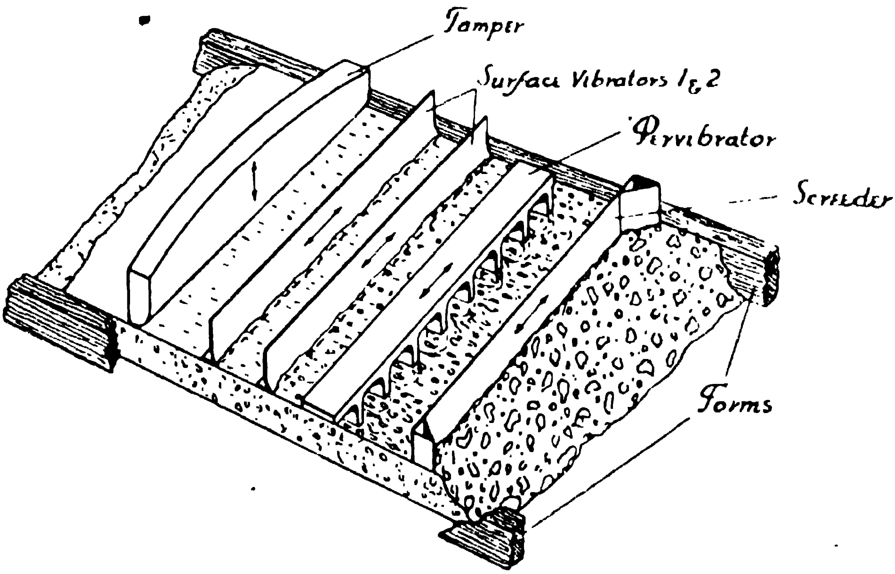
A few precautions should be observed when placing concrete. Whenever the mixer is shut down long enough for the concrete to commence hardening, a square butt joint should be

made. Even when the mixer is stopped for only 10 or 15 minutes the new and old concrete should be thoroughly sliced together to make sure that no cleavage plane is left. It is advisable to use concrete a little deficient in coarse material next to joints.

Tamping and Finishing Concrete.—After the concrete is placed roughly to the required section of the slab, it is consolidated by means of a tamper (shown in the appendix) weighing not less than 7 lbs. per lineal ft. The concrete is tamped transversely, the tamper being worked off the side forms. Immediately after the tamping is completed, the surface should be inspected for high or low spots and any needed correction made by adding or removing concrete. The surface should then be finished with a hand float. Just prior to the final finishing operations, the surface should be tested with a straight-edge (shown in the appendix) 10 ft. in length, laid parallel to the centre line of the road and any deviations should be immediately corrected. The surface should finally be finished with a smoothing board which is worked transversely from the side forms or from the finisher's bridge. Too much tamping and over-finishing which brings an excess of mortar to the surface should be avoided. Any superfluous water or laitance on the surface should be removed by drawing an empty cement bag across the slab.

In recent years of mechanical development and tendency to replace all manual labour by machinery, different types of machines have been used in Europe and America to carry out most of the operations such as mixing, placing, tamping and finishing concrete in the construction of concrete roads. Until a few years ago simple machines for tamping and finishing were used, but with the introduction of vibratory methods of consolidating concrete, very interesting machinery has been developed for concrete road construction. Consolidating concrete by means of mechanical vibration has very great advantages over the usual tamping either by hand or machine. It permits the use of dry concrete mixes to be used and accomplishes thorough and uniform consolidation throughout the body of the structure producing very dense and strong concrete. In the beginning only surface vibration was used for the construction of concrete roads, but lately pervibration (i.e. vibration applied internally) has also been employed for road slabs. The

description and working of the Henius Pervibrating Machine will be found of unusual interest.



Diagrammatic Illustration of Vibration

The machine consists altogether of five vibrated tools (as shown in the diagram). First comes the screeder, which might be better described as a blader, and serves the purpose of initial levelling and taking off excess material. It has a lateral vibration of about 1/15 inch amplitude and a frequency of vibration of 1,600 per minute. Following this comes the pervibrator, also with lateral vibration, but working at 3,200 vibrations per minute. It consists of a heavy bar, in appearance like an open-toothed comb, the teeth being strong steel blades having a streamlined contour. The depth of the teeth is determined by the depth of the material being laid. One might expect that these teeth would leave obvious furrows in a very dry concrete, but actually the material starts to flow like very wet concrete as the teeth move forward, and closes round them as they pass, leaving no gap and no free laitance on the surface.

The pervibrator is followed by two surface vibrators, both oscillating at a frequency of 1,600 per minute, with a lateral vibration of the same amplitude as the rest, and finally a tamper working at the same speed but with a vertical movement.

The Machine is of Danish origin and has been very successfully used on road work in Denmark. It was recently demonstrated on the Kingston By-Pass, Surrey, England and it is interesting to note that immediately after the consolidation of the concrete it was possible to walk about on it without making any impression.

Great economies can be effected in the cost of concrete roads by employing vibration as lean mixes can be safely used to obtain the strength secured with normal methods. On the Continent it is common practice to use a 1 : 4 : 7 mix without reinforcement where vibration is employed. Time and labour can also be saved with such machinery, as daily outputs of 700 to 900 sq. yds. are obtainable.

Curing.—After the final finishing operations are over, the slab should be covered with canvas or empty cement bags as soon as it can be done without damaging the surface of concrete. This should be kept wet by frequent sprinkling with water for several hours until it can be replaced by ponding with water or any other form of curing. It is most important to keep the concrete slab wet for the first few days to prevent the evaporation of the moisture from concrete which is necessary for the hydration of cement. Strength lost by lack of moisture during the first few hours and days cannot be regained by subsequent curing.

Curing in this country is generally done by ponding with water and sometimes with a covering of wet earth, hay, or a sand layer.

There are other methods of curing which are frequently used such as Calcium Chloride, bituminous coatings or waterproof papers.

The period of curing should be 14 days with normal cement but with rapaid-hardening cement it may be 7 days. In the former case the road should be opened to traffic after 3 weeks, in the latter, it can be done immediately after the curing is completed.

Great improvements have been made during recent years in the design and construction of concrete roads and the important problem of cracking has also been properly investigated. Scientific research and reports on several experimental works

carried out in the past few years have disclosed causes of cracking and suggested possible methods of overcoming this trouble. Cracks in a concrete road may be due to any of the following causes, individually or the combination of two or more causes.

1. Inadequate design.
2. Bad subgrade.
3. Inefficient joints and insulation.
4. Bad workmanship.
5. Improper curing.

1. *Inadequate design.*—Concrete roads constructed with inadequate section and strength have cracked and failed when subjected to heavy wheel-load traffic. Such structural failures are rare in this country as in the past very heavy sections with rich strong concretes have been used. But with the present knowledge of concrete and the factors affecting the design of road slabs, a very safe and economical design can be worked out with certain confidence. For proper design of concrete road slabs, accurate formulae have been evolved which have been verified both by mathematical analysis and actual test results.

The formula advocated by the Permanent International Association of Road Congress is given below.

$$D \text{ (the edge thickness in inches)} = \sqrt{\frac{3W}{S}}$$

when W = the max. wheel load in pounds

S = the maximum allowable fibre stress in pounds per sq. in. which is generally taken as 250 to 300 lbs./sq. in.

The central thickness is taken as seven-tenths of the edge thickness, which gives uniform strength in the slab.

Cracks sometimes appear at the corners of slabs near the transverse joints. An effective method of preventing these cracks, which has been tried in America, is by providing longitudinal shear bars. These are $\frac{3}{4}''$ dia. mild steel bars inserted about 6″ from the edge of the slab and parallel to it. They extend from end to end of the slab and are placed about 2″ below the surface. They are painted or greased to break the

bond with concrete so as to permit the bar to take the full shear and bending in load transmission.

2. *Bad Subgrade.*—In many cases the cracks are due to a bad subgrade. This condition is either the result of ununiformly compacted subgrade, not properly drained subgrade, or subgrade consisting of soils whose stability is affected by variation in moisture condition. The first two conditions can easily be avoided by taking necessary precautions.

The last condition, however, presents a special problem in subgrade preparation. These subgrades consist of clayey soils, which change greatly in volume due to variations in moisture condition ; in shrinking they form into fissures causing cracks in the road slab, and while swelling heave and break the slab. They are also very difficult to drain. The usual method adopted in this country to overcome such bad subgrade conditions is to provide about 6″ layer of porous material such as clinker or sand between the slab and the soil, ditches along the sides of the road to effect proper drainage, and also reinforcement in the concrete slab. A more efficient and economical method is being developed now in America for improving unstable subgrades by means of soil stabilization. The subgrade is either stabilized with the use of suitable soil mixtures with the addition of some deliquescent chemical such as Calcium Chloride or cohesive agents such as cement, bitumen tar, etc.

3. *Inefficient Joints.*—Transverse or longitudinal cracks frequently occur in the road slab owing to bad design of joints or restrained movement of the slab over the subgrade. These cracks can therefore be easily avoided by properly constructing transverse and longitudinal joints at the recommended spacings with dowel bars in their correct position, efficient expansion joint material, and with a good insulation such as tarred paper under the slab which allows its free movement during expansion and contraction.

4. *Bad Workmanship.*—Cracks as the result of bad workmanship are due to a weak concrete section produced owing to several causes such as dirty and unsuitable aggregates, faulty proportioning of concrete, inadequate mixing, use of too much gauging water, insufficient tamping, and improper finishing.

With careful supervision and control over the various details and operations it should be possible to remove the cause of such cracks.

5. *Improper Curing.*—Improper curing causes rapid drying of the concrete slab which results in cracks. This drying effects evaporation of the moisture in the concrete which is necessary for the complete hydration of the cement and thus produces very weak concrete. Specially in the initial stages of its hardening, concrete shrinks as it dries and tensile stresses are set up while it is too weak to withstand them resulting in shrinkage cracks. Therefore all precautions should be taken to protect the concrete slab, immediately after it is laid, from drying out due to winds or hot dry weather.

India being primarily an agricultural country, its development largely depends on the facilities provided for marketing its produce. This necessitates the provision of some means of communication to enable the agriculturist to carry his produce economically to the nearest railway station. There are large tracks of land in this country without any communications at all, but even where these exist they consist of a few water bound macadam roads but mostly "earth" roads which are impassable during wet weather. Moreover, as the principal vehicle for the transport of goods in this country is the bullock cart, these roads rapidly break up under the traffic and become very costly to maintain. To improve such a condition a better type of road is found necessary. This, however, owing to financial considerations should be very cheap as well as durable. Concrete as stated above has proved to be the best road surface for iron tyred traffic, and an economical solution is offered by concrete wheel tracks or "Creteways." Several lengths of these tracks have been constructed all over the country with very satisfactory results. These are 2′ wide strips 6″ thick and are spaced 3′ 3″ apart.

The construction of these tracks consists in excavating 2′ wide and 6″ deep trenches to proper grade and alignment and filling these with properly mixed concrete on an insulation layer of either sand or waterproof paper. All other details and operations of construction are the same as for the all-concrete road.

As these tracks have to be constructed in the country far removed from the cities, it generally becomes difficult to exercise proper control during construction. To overcome this, the Author is carrying out experiments with precast blocks 6′ long, 2′ wide and 6″ thick with hollows on the under side.

These blocks can be manufactured at conveniently situated depots, provided with vibrating machines, under expert supervision. After these have matured they can be taken along in bullock carts or lorries to the site and before being laid in the prepared trenches, the hollows are filled in with mud or very lean concrete They are laid to correct levels and alignment and finally the joints are poured in with a mixture of bitumen and fine sand. The cost of such a track works out to about Rs. 7,000/- per mile. It will be of interest to mention that an experimental length with such precast blocks is at present being laid at Akola.

In the Author's opinion these precast block creteways should provide a very easy and economical solution for improving rural and approach roads to the cities.

DISCUSSION ON CONCRETE ROADS AND THE BULLOCK CART.

The Author in introducing his paper asked those present to consider one or two outstanding problems, connected with concrete roads in India. He said that the question of initial cost of roads in this country occupied a more important position than it should and that it was the ultimate cost of the road including maintenance over a period of 20 or 30 years which really counted.

He explained the controversy that was going on in connection with the increase of thickness of the edges of the concrete roads, for whereas in America this was common practice, in England they have decided that it was unnecessary. The Author pointed out, however, that the thickness of roads both in America and England are as general rules far greater than those in India. It was possible he said to argue in favour of both types but he himself considered that in thicknesses 5″ or under it was advisable to thicken the edges. He then referred to the remarks made at the Annual Dinner by the Honourable Mr. Y. M. Nurie, Minister of Public Works, from which it was clear that he was interested in getting low cost roads to connect up villages with each other and with main arterial roads and the Author said that as far as he knew there was no better method than the concrete track which could be laid on virgin soil. He then explained the works being done in the Concrete School at Grand Road where blocks 6′-0″×2′-0″×6″ were being cast on a vibrating table having three hollows on the underside of the blocks and a tongue and groove system of joining. These blocks were set approximately 3′ apart to make wheel tracks of bullock carts and light lorries and these tracks could be laid across country for as little as Rs. 6,000/- per mile.

MR. G. E. BENNETT in opening the discussion thanked the Author and referred to the remarks on rolled concrete and asked how long this rolling should go on and any other details which the Author could give. He briefly discussed the value of reinforcement in concrete and wanted to know the mix used in the formula on page 153.

MR. S. B. JOSHI suggested that in lieu of the joint for precast block the ends of the block be chamfered of at 45°. He mentioned that cut stones had been used in certain parts of India for wheel tracks successfully. He thought that vibration had a better effect on concrete than rolling, and that in lieu of tar paper a mix of two parts of clay and one of cow-dung could be be used successfully. Reinforcement also could be very well made up on the spot by making mats of mild steel rods preferably Tata Steel. He hoped that there was no intention of putting all the blame of damaged roads on to the bullock carts.

MR. S. B. TYABJI said that slabs of stone had been successfully used in Idar State as wheel tracks.

MR. S. H. MEHTA wanted to know what the depth of the precast slab should be and briefly discussed barrelling, cambering and super-elevation of roads.

MR. K. D. BHAGWAGAR said he thought that reinforcement was bound to be helpful in dealing with roads on black cotton or other variable soils. He was afraid that the method of joining the slabs might induce tilting.

MR. R. K. NARIMAN said that he thought strips in certain parts of the country could be made in *Kankar.* In the Gold Coast and other parts of Africa, iron tyres on the bullock carts were prohibited and that pneumatic types were getting popular. He also referred to salt in certain soils which might have a detrimental effect on the concrete.

MR. W. B. BURFORD said that overseers and mistries should be trained to take charge of concrete road work, as technique was getting more and more specialized. He was doubtful if the average contractor could use a mechanical vibrator successfully. He wanted a table showing the life of

various types of roads under different concentrations of loading and inquired what the density of traffic was on the Bombay-Poona Road. He referred to the two track roads in Germany with dividing hedges. He thought that the pneumatic tyres was a solution to the bullock cart problem and said that intensity of loading in lbs. per sq. inch was what had to be thought.

MR. E. A. NADIRSHAH said that he was definitely in favour of concrete for roads but there were one or two problems which were still awaiting solution, one being the pulling up of the streets for repairs to the underground services and he thought that this should be closely studied. He was of opinion that concrete kerbs with angle iron edgings might displace stones. The one great advantage of concrete roads over other types was the residual value of the concrete base after the top had worn out.

MR. S. N. GHOSE said that he had seen moffusil municipalities trying to adopt concrete roads within their municipal areas. At Barisal they tried a small length of road in an area where there was a heavy traffic. After 2 years, as they found that the surface was kept very well and the cost of maintaining the road very small, they did a big length and contemplated to have most of the heavy traffic roads to be put in concrete. The only drawback was that when iron tyred traffic passed over the section it made too much noise.

At Khulna also they were experimenting with a short length of concrete road.

MR. J. M. RAY pointed out that reinforcement of cement concrete roads was unnecessary unless the subgrade was weak. In view of the longitudinal joints in the road surface being cut into grooves by cart wheels he suggested as a remedy to minimise these joints as far as possible. Transverse joints were usually allowed at distances of 35′. On the same basis the longitudinal joints, wherever possible, should also be not less than 35′ apart. Thus there should be no longitudinal joint in roads of 35′ width or less.

MR. H. P. BHAUMIK, O.B.E., asked for information whether edge-thickening and dowelling were in actual practice adopted in Calcutta. It was gathered from Engineers connected with

road design and construction in Calcutta that edge-thickening and dowelling were not used there. Concrete slabs were used instead, in Calcutta as described by the author in para (b) of page 147 of the paper. One member was of the definite opinion that the thickening of the edge and the use of dowels were expensive and the use of under-slabs at joints had given quite satisfactory results. The author stated that the latter method was tried in England with *not* very satisfactory results. Further remarks of the author on this point would be welcome.

Mr. Bhaumik also drew the attention of the members present to the author's remarks about Curing (page 152). The practice followed in this respect did not appear to be uniform. In some cases the surface was not covered with wetted canvas or empty cement bags for 24 hours after the finishing operations were over Road layers should have definite instructions on this point, as according to the opinion of the author, "strength lost by lack of moisture during the first few hours and days could not be regained by subsequent curing." Similarly there was some uncertainty in the minds of engineers as to the period of curing. Some favoured a minimum period of 21 days, others 14 days, and still others only 7 days or less. With the modern quick setting cement, it was for consideration whether a prolonged period for curing was necessary. It is true that the setting or hardening process in cement concrete structures continued for a pretty long time, but the point for determination was the minimum period which should be allowed with the quick setting cement which was being used at present. It would be interesting to know the results of specific experiments, if any, which might have been carried out in India to determine the "safe period" which might be adopted in this country. The results of experiments carried out in cold countries could not obviously be adopted *in toto* in India, as due to higher prevalent temperature it was possible that chemical action took place more quickly in the tropics than in colder climates.

Mr. Bhaumik also raised the question of the kinds of aggregates which should be used in suburban and district board roads in places where stone metals were not available or very difficult to procure. The district roads in East Bengal and some parts of North Bengal were the cases in point. He asked whether a road constructed with hard *Jham-*

ma aggregates would be suitable for such places if the traffic was not heavy? He liked to know the experience of practical engineers. In East Bengal and even in some parts of west Bengal roads were metalled with ordinary broken bricks and *Jhammas*. The consensus of opinion was that a road constructed with *Jhamma* aggregates would not be a success, and would not be worth the expense involved.

The question was also raised whether with machine mixed concrete it would be still advantageous to use a vibrating or pervibrating machine on the site of work while actually laying the concrete. It was not used in Calcutta and the local road engineers were of opinion that such a machine was only useful where the concrete was not mixed by a machine. Mr. Bhaumik was of opinion that the vibrating machine might be useful even in the case of machine mixed concrete. It might help in the even-laying and consolidation of the stuff on the road surface and giving a better uniformity to the prepared surface. The author's remarks on this point would be welcome.

Lastly the attention of the members was drawn to the author's suggestion about the concrete wheel-tracks or Crete-ways for bullock carts in rural areas. Though the opinion seemed to be divided about the utility or economy of such tracks, Mr. Bhaumik was of the opinion that the suggestion was a practical one and ought to prove very effective for mofussil roads in Bengal which were made practically impassable by bullock cart traffic during the rains.

MR. S. K. CHAKRAVARTI observed that the maintenance of concrete roads in particular was more costly and troublesome than various other kinds of roads, inasmuch as the concrete road surfaces had very often been found to have corrugations either transversely and longitudinally and patch repairs had very little effect on these surfaces.

He stated that worse deterioration took place in concrete roads near the edges due to unequal strength of materials of the roads themselves and that of the binding edges. It had, however, the advantages of usual roughened surfaces consistent with motoring, driving, travelling in carriages—drawn by horses, having very little chance of slipping of horses' feet, often noticed

on tarmac road, especially after a small shower of rain or early morning in cold weather, when the road was fairly wet with dew in a more humid climate.

MR. J. GANGULY said that concrete roads were coming to use both in cities and main trunk roads to mofussils. However there were limitations to their use. India is pre-eminently an agricultural country, about 90 per cent of its population is rural. It would be well to construct the main trunk roads with the material suggested by the writer. Apart from the traffic carrying purpose for which a road was chiefly meant, a village road had to serve other purposes, *e.g.*, as children's play ground, elder's meeting place, a resting place for the animals and so on. If these roads were constructed with concrete and connected with the main trunk roads, there would be great danger of their being used by motorists and thus it would disturb the normal life in villages. Again there were towns where drains and water supply installations did not exist. It would be erroneous to pave these roads with concrete as the cost of laying water-mains and constructing sewers afterwards would be considerable. The concrete roads had another disadvantage. In big cities having underground sewers, water-mains and electric cables (underground), the cost of periodically opening the roads for the above works was prohibitive and after the restoration the surface seemed to be very ugly. There were also the transverse expansion joints at the intervals of about 30 ft.; at summer a passing motorist experienced bad jerks due to exapnsion of the asphalt in the joints.

The AUTHOR thanked the members of the Institution for the great interest they had shown in his paper. He said that 1:2:4 was the mix used in the formula on page 153. He thought that the tongue and groove joint described was more likely to be successful than the method suggested by Mr. Joshi as the latter would allow the blocks to sink or rise according to the sub-soil conditions. There was no objection to making up mats of mild steel for reinforcement purposes. He said that the average bullock walked in front of the wheel of his cart and nine times out of ten preferred to walk on concrete than on any other road surfaces as the traction required was less. The intensity traffic on roads varied with the time of the year and on the

exact location of the point of counting but that more statistics of this nature would be of great value. The question of breaking open roads in cities on account of repairs to underground services was receiving the attention of road engineers everywhere. One method was to have precast concrete slabs over the main line of services but the best possible solution was to put services under the pavement.

With reference to Mr S. N. Ghose's remarks the Author said that it was difficult to see how a certain amount of noise as between iron tyred wheels and concrete could be avoided. The best solution was for bullock carts to adopt pneumatic tyres.

With regard to the points raised by Mr. J. M. Ray the Author said that reinforcement in concrete roads was as a rule unnecessary unless the subgrade was weak. Bonded concrete roads however needed reinforcement as part of their design. Longitudinal joints in concrete roads should be avoided as far as possible and where they were necessary they should coincide with a traffic dividing line. The Author did not agree that longitudinal joints could be 35′ apart. Experience had proved that not more than 14′ breadth of roadway was permissible in India without a longitudinal joint owing to the warping effect due to temperature changes.

Commenting on Mr. H. P. Bhaumik's remarks the Author said that edge thickening was adopted in Calcutta, also dowelling. The Improvement Trust had in certain places used concrete slabs underneath transverse joints. The Author did not think that edge thickening was necessary where the thickness of the concrete road was more than 5″. Where, however, it was less than 5″ he still considered it necessary. He agreed with Mr. Bhaumik that curing should start at the earliest possible moment short of disturbing the new surface. Also any strength lost by lack of moisture during the first few hours would never be gained in subsequent curing.

The Author was in favour of 14 days curing for ordinary cement and 7 days for Rapid Hardening cement. As far as he knew no specific experiments had been carried out in this country with regard to the best period of curing.

In many instances it had been found that overburnt brick made very good aggregate for roads which did not carry very heavy traffic but so much depended on the brick that he did not recommend this as a general rule.

He was definitely in favour of vibrating the concrete after it had been laid in the roadway but special machines were necessary for this and he hoped that some of these would be introduced into India shortly in connection with the concrete roads in the Bombay Presidency. The concrete should be mixed where possible by machinery and vibrated by a road finishing machine but it was obvious that these road finishing machines could only be economical for long stretches of roads. He was convinced that Creteways for bullock carts for country roads would prove their utility in the long run.

The Author did not agree with Mr. Chakravarti when he said that maintenance of concrete roads was more costly and troublesome than of other kinds of roads. Concrete roads properly laid with good material overcame all the difficulties suggested by Mr. Chakravarti.

As regards Mr. Ganguly's remarks the Author said that the important criticism was in connection with the drains, water-mains and services under roads. This trouble could only be got rid of by laying all services in future under pavements as was being done in Cities of America, Europe and the United Kingdom.

Expansion joints when properly made did not give jolts to motorists. There were many concrete roads in India, on which a car could be driven at 40 miles per hour without the least discomfort.

COOPER SPLIT ROLLER BEARINGS AND THEIR APPLICATIONS TO INDUSTRIAL MACHINERY

BY

MR. C. A. ABLETT, O.B.E. (Mil.), B.Sc., (Lond.). M. Inst. C.E.

(This is not an Institution paper but read at the Bengal and Bombay Centres).

ABSTRACT.

This paper describes and illustrates the construction of Split roller bearings. It shows how the joints between the two halves of the races can be relied on. The paper then continues to show how split roller bearings are fitted up in pedestals, in axle-boxes and are used for many industrial applications such as cement mills, steel works, colliery screens, cables stranding machinery etc.

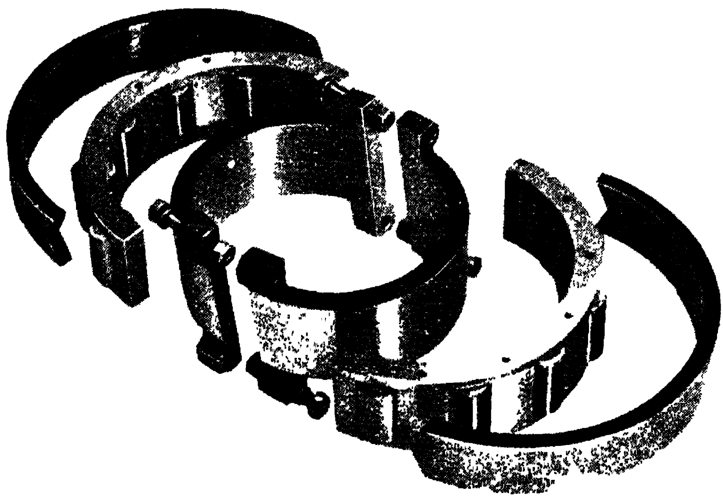
These industrial applications are utilised to exemplify the advantages of roller bearings and the additional advantages offered by split roller bearings, namely :—

1. Increase of production from the plant by avoiding breakdowns and interruptions to production.

2. Increase of production owing to higher speed.

3. Savings in cost of production arising from savings in power and savings in maintenance.

Mr. Chairman and Gentlemen,



No. 1

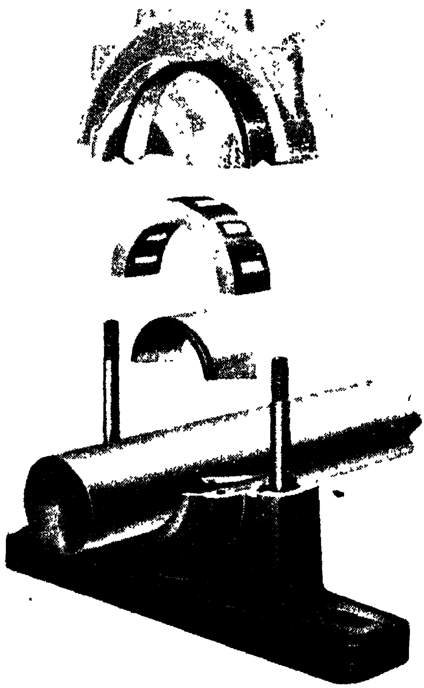
Illustration No. 1.—Shows the principle of the split roller bearing and in the centre of this illustration the inner race can be clearly seen in two halves, which clamp on to the shaft or axle, and may be secured thereto by the bolts shown in the illustration, or other alternative clamping method such as split clamp rings.

It will be seen that the joints between the two halves of the inner race are not parallel to the axis of the shaft or axle, but are set at an angle thereto so that there is countinuity of contact between rollers and races while passing over the joints.

The two halves of the cage containing the rollers can be clearly seen and the two halves of the outer race, in which the joint is fish-tailed.

The inner race, the outer race and the rollers are all made from special alloy steel oil hardened and accurately ground.

These essential parts of the split roller bearing are used in many ways.



No. 2

Illustration No. 2.—Shows how these parts are fitted up as a pedestal bearing, and also shows how self-alignment is attained, as the housing which contains these inner parts is made spherical so that it is free to swivel in all directions in the pedestal.

Similarly these inner parts are fitted up in simple split housings for hangers, wall brackets etc., for supporting line shafting.

No. 3

Illustration No. 3.—Shows how these essential parts of the split roller bearing are fitted up in an axle-box and the split roller bearing axle-box is a very marked improvement over axle-boxes with solid roller bearings, whether they are fitted between the wheels or outside the wheels, because the inner races of the split roller bearing can be clamped on to the journals of existing axles, and it is quite unnecessary to provide special axles, or to do a considerable amount of machining on existing axles as is the case with solid roller bearings.

It is well-known that the races of roller bearings, after they have been in use, work themselves into very intimate contact with the axle. In the case of solid roller bearings this frequently makes the races difficult to remove. The split roller bearing is a definite improvement as this difficulty disappears, the inner races can merely be lifted off.

A point of interest is that as far as the Author knows the first occasion on which roller bearing axle-boxes were used in the East was at Penang, Straits Settlements, in 1924. These were split roller bearing axle-boxes and they have proved so successful that their use at Penang has been greatly extended.

Much discussion has taken place about the advantages of roller bearing axle-boxes as compared with oil or grease lubricated axle-boxes, but the following point seems to have been overlooked and that is that where oil or grease lubricated axle-boxes are used the journals wear. In course of time they wear down to such a size that they are no longer safe and have to be condemned and replaced by new axles. Roller bearing axle-boxes avoid the expense of replacing axles as the hardened steel inner races protect the journals from wear so that axles, which are correctly designed to avoid fatigue, are given an indefinite life by the use of roller bearing axle-boxes.

No. 4

Illustration No. 4.—Shows one of a set of 18″ bearings which were fitted to the trunnions of a wet grinding mill in a Cement Works in 1913. The mill weighs some 35 tons and the bearings have been working satisfactorily ever since under the dirty conditions which cannot be avoided in a cement works, which are very clearly shown by the illustration.

Certain engineers who have not had experience of the working of split roller bearings are disposed to have doubts on

the joints between the two halves of the races and to say that they anticipate that the races will fail at the joints.

Such doubts and anticipations are definitely not borne out by the facts, there are very many split roller bearings which have been running satisfactorily for periods of twenty-five to thirty years with no signs of failures at the joints, and Illustration No. 4 affords but one example out of many.

The progressive spirit of India is shown by the fact that many split roller bearings have been satisfactorily at work in India for over twenty years.

Roller Bearings like any other type of machinery do occasionally prove troublesome, and may fail owing to misuse, excessive overloading, due sometimes to settlement of foundations, and other such causes, but in the Author's experience such troubles or failures have manifested themselves in the granulation of the inner races, and the Author knows of no case of failure at the joints.

Before proceeding to some definite industrial applications of split roller bearings, the advantages of the roller bearing may well be considered and how these advantages may be increased by adopting the split construction of the roller bearing in place of the solid.

These advantages may be briefly summarised as :—

1. Increase of production from the plant by avoiding breakdowns and interruptions to production.
2. Increased production owing to higher speed.
3. Savings in cost of production arising from savings in power, and savings in maintenance.

Illustration No. 4 is an example of split roller bearings which have given over twenty-five years satisfactory service and it also affords a striking example of point No. 1.

When a Cement mill is provided with white metal or bronze bearings it is found necessary to change the bearing-shells about every four months owing to the wear which takes place due to the dirty conditions, and spare bearing-shells are kept in a cement works to be ready for this purpose, but the change occupies about nineteen hours during which the whole section of the cement works, which depends on that particular grinding mill, is stopped and such a stoppage is a costly business, as it reduces output.

Regarding this economically, the cost of a single stoppage may easily be more than the cost of providing split roller bearings for a cement grinding mill. One must remember the fact that these large split roller bearings are distinctly cheap in capital cost, as compared with solid roller bearings, split roller bearings are manufactured from rolled alloy steel flats forged to shape and so are definitely cheaper than the expensive forgings required for the manufacture of large solid bearings.

Further examples of point No. 1, are afforded by some of the illustrations which follow.

The Author came across a striking example of Point No. 2 some months ago, when visiting Nawalapitiya in Ceylon where a solid roller bearing supporting some shafting driving Tea machinery had broken down. The obvious course to get going quickly would have been to have broken the solid bearing off the shaft, and to have replaced it with a split roller bearing when the tea factory might have been going again in about half an hour.

It happened that the Superintendent of that factory was on leave, his assistant would take no responsibility and insisted that the faulty solid bearing be replaced by another of the same sort.

To do this a length of shafting had to be uncoupled and taken down, belts, pulleys etc., had to be taken off, and a new solid bearing slid along the shaft. The engineers' bill for doing this work was about Rs. 300, but worse followed as the work took over three days, the whole of the tea in the factory was damaged resulting in a loss of about Rs. 3,500 so that the breakdown of a single solid bearing, worth something like Rs. 30 involved a loss of nearly Rs. 4,000. This would have been saved by the use of a split roller bearing.

In considering the question of power saving, it is not generally realised that there is a very wide difference between the power consumption of various types of roller bearings and as the Author holds the patent rights for making any type of roller bearing as a split roller bearing he is fortunately able to deal with this point in the most impartial manner.

The late Professor Unwin gives some interesting figures in his book on machine design. He states the following co-efficients of friction :—

Plain Roller Bearings	0·001	to	0·0015
Roller Bearings with Spiral Spring Rollers	0·004	to	0·007
Taper Roller Bearings	0·002	to	0·004
Double row Roller Bearings of the self aligning type with Barrel Shaped Rollers ..	0·002	to	0·003

From these figures it will be seen that certain types of roller bearings may consume seven times as much power as other types.

It may appear a trivial matter to quote co-efficients of friction running into the third place of decimals, but the figures are important just as the mileage of a motor car per gallon of petrol is also important, although a gallon of petrol is ·0035 of a ton.

The above consideration shows that as the split roller bearings in Illustrations 1, 2 and 3 are provided with plain rollers, economy in power consumption is one of the features which has been aimed at.

Professor Unwin in giving the above figures mentions the names of certain manufacturers, but it has been considered advisable to omit these names from this paper, which is only concerned with types of bearings.

The Midland Railway of England some ten years ago fitted up a rake of coaches with the kind of roller bearings which have a co-efficient of friction according to Professor Unwin of from ·002 to ·003, they then carried out a series of tests between London and Leicester, and the results published in a paper before the Institution of Mechanical Engineers, went to show that the results of the roller bearing tests were about equal to the results of tests made on a similar rake of coaches with oil lubricated axle-boxes.

The British railway engineers tended to conclude that roller bearings offer no particular advantage for railway work and consequently their adoption has been very slow in Great Britain.

This conclusion is a false one, arrived at by a misunderstanding of the differences in co-efficients of friction of roller

bearings. Had the rake of coaches in question been fitted with roller bearings having co-efficients of friction of ·001 to ·0015 the results of the tests would have been very different and the advantage of fitting roller bearing axle-boxes would have been demonstrated in a remarkable manner.

Some engineers are inclined to regard the roller bearing as something which is fragile, but experience has shown that this is altogether a mistaken view as the roller bearing is well suited for taking shock loads. Expressing this in theoretical language the stresses in a roller bearing vary as the square root of the load on it and consequently if one considers a roller bearing rated for a load of ten tons, and this load be suddenly increased by some shock to 40 tons the stresses will only be doubled, they will not increase four times as would be the case with an oil or grease lubricated bearing.

The expression "line of contact between the roller and the race" is sometimes rather lightly used but it must be remembered that the rollers and the races are elastic structures, that they deflect under load and under ordinary conditions one finds a definite contact area between the rollers and races something of the order of 2/100" wide. If the loading on a roller bearing is increased by such a shock load as is referred to above, both the rollers and the races deflect to a greater extent so that the width of the contact strip widens and therefore whilst the stress between the roller and the race is increased there is at the same time a greater area subjected to stress. Consideration of this point will easily show the basis of the above statement that the stresses vary as the square root of the the loading.

As a practical example one can compare the rollers of a roller bearing with a motor car tyre. One knows that the contact between a motor car tyre and the road is not a line but there is contact over a considerable area due to deflection of the tyre. The same sort of thing happens with the rollers of a roller bearing only in a lesser degree.

All these points can be expressed mathematically but as this paper is intended to be a practical paper to appeal to practical engineers, it has been considered better to omit mathematical expressions.

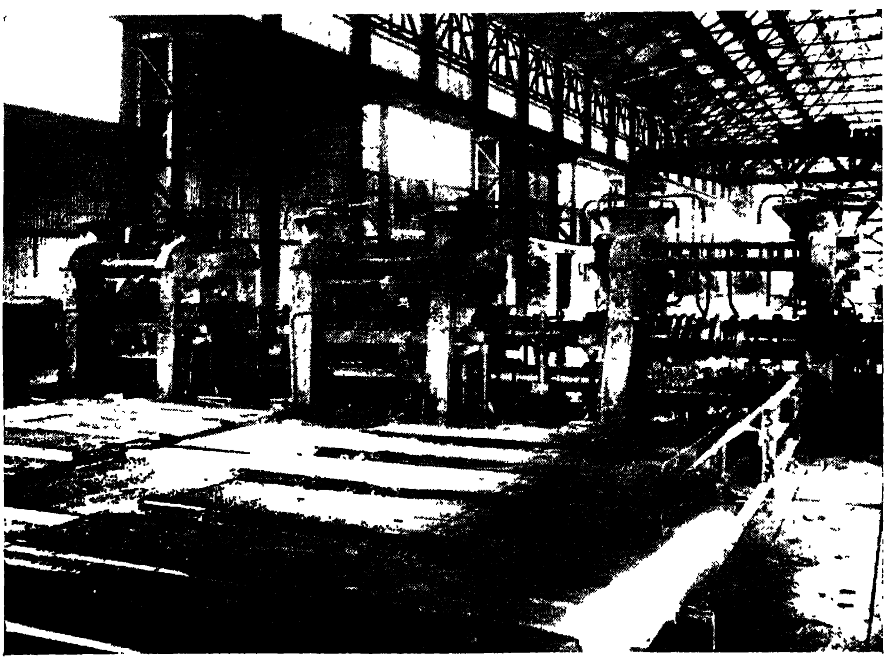
So far reference has been made in this paper to split roller bearings, but the Author holds the patent rights for split ball

bearings. He has manufactured them successfully and such split ball bearings have been running with successful results since 1929, over nine years.

It has, however, not been considered worth while to exploit these successful results commercially, for one thing there is the disadvantage of ball spin which takes place in a ball bearing. By ball spin is meant rotation of the balls about an axis which is not parallel to the axis of the shaft. Such a ball spin is easily set up by any disturbing factor such as end thrust, and leads to the races wearing out and having a comparatively short life.

Roller bearings are entirely free from this disadvantage and for this and other reasons, engineers in Europe are tending to restrict the use of ball bearings to quite small sizes, under $2\frac{1}{2}''$.

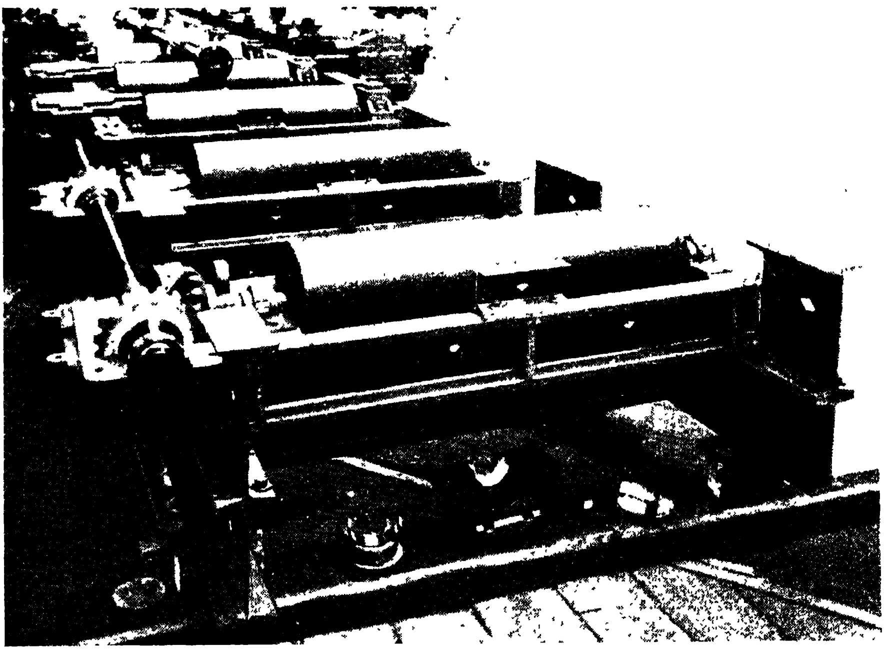
Turning now to some industrial applications of split roller bearings :—



No. 5

Illustration No. 5.—Shows an 18" steel rolling mill at the works of the Skinningrove Iron Co., Ltd., Nr. Middles-

brough, Yorkshire, England, and in this illustration a white hot billet will be noticed which is being returned to the rolling mill by the live roller gear rollers, which will be seen let into the flooring in front of the mill.



No. 6

Illustration No. 6.—Shows a portion of this live roller gear partially stripped and photographed at the works of the manufacturers. In this illustration it will be seen that the live rollers are positively driven by bevel gears, and that both the live rollers themselves and the side shafts carrying the driving bevels are being supported on split roller bearings, a dismantled split roller bearing will be seen in the foreground of the illustration.

The white hot billet in being rolled down to the required section is passed backwards and forwards through the rolling mill, it is carried up to the rolling mill by the live roller gear then passed between the bottom and middle roll on to a lifting table behind the mill which is also equipped with live roller gear. The lifting table then lifts, the live roller gear reverses

and carries the billet back so that it passes between the top and middle roll and on passing out of the mill falls with a thump, some 18″, on to the live roller gear in front of the mill which is seen in illustration No. 5. As this billet weighs a ton or upwards, and goes through the mill every few seconds, the shock loads which the live roller gear bearings have to withstand will be appreciated when it is considered that a billet weighing a ton or upwards falls with a thump a distance of 18″ on to them every few seconds.

The results of this 18″ mill at the Skinningrove Iron Works, have proved to be so good, that at the present time a similar 18″ mill of which the live roller gear is fitted with split roller bearings is being installed at the new works of the Steel Corporation of Bengal at Burnpur near Asansol in India.

The mill shown in illustrations Nos. 5 and 6, affords a capital example of increased production obtained by the use of roller bearings. It is well known that when a rolling mill is worked smartly it may easily take say two and a half seconds for the passage of the billet through the rolls, of which time the billet is only between the rolls for one second and is on the live roller gear for one and a half seconds. Obviously the one second is the time during which useful work is being done and the one and a half seconds during which the billet is on the live roller gear is idle time.

The effect of fitting roller bearings to the live roller gear has been to make the live roller gear reverse much more rapidly than would be the case if oil lubricated bearings were used, and consequently this idle time of one and a half seconds is cut down so that the maximum output of the mill is some 20 per cent more than it would have been had oil lubricated bearings been used.

Looking at this financially, roller bearings make an extremely good financial proposition. An 18″ rolling mill with its necessary furnaces, buildings and other accessories probably costs something like Rs. 20,00,000. The roller bearing

equipment probably costs something like Rs. 55,000 so that the expenditure of Rs. 55,000 on roller bearings has increased the production of a Rs. 20,00,000 plant by some 20 per cent.

It is interesting to note that the live roller gear of the 32" reversing rolling mills at Messrs. John Lysaghts Ltd., Normanby Park Steel Works, Scuntharpe, Lincolnshire, were equipped with split roller bearings in 1932 and the equipment of the live roller gear of the 36" cogging mill followed shortly afterwards. Since this live roller has been equipped with split roller bearings the maintenance costs of bearings, apart from greasing every three months, have been reduced to nil, and there have been no stoppages of the rolling mills due to trouble with bearings.

Previously when bronze bearings were used in the live roller gear they suffered constant damage from highly abrasive mill scale, which is formed on the white hot ingots and is broken up to a fine dust in the rolling mills, with the result that stoppages took place owing to bearing troubles, and the engineers had to be doing constant repair work during holidays to keep the live roller gear in good working order.

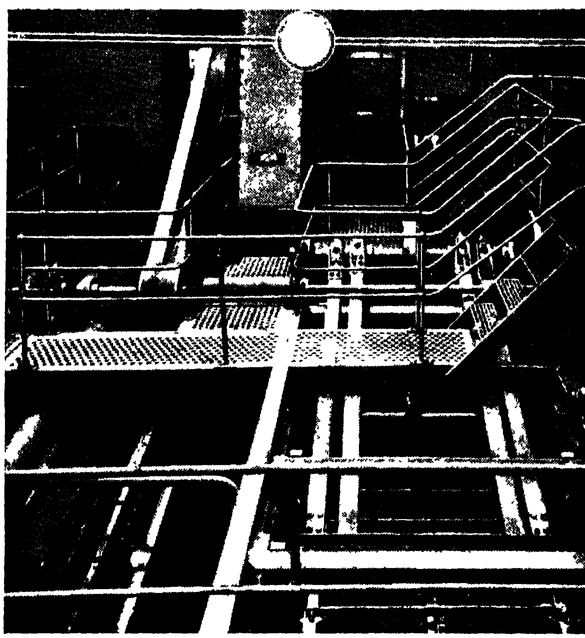
When such a rolling mill is stopped the cost of the stoppage, taking into account the loss of production, and idle capital charges, amounts to about Rs. 70 a minute so this figure will give you a good idea of the savings effected by fitting the live roller gear with split roller bearings. The figure of Rs. 70 a minute for the cost of a stoppage is a well-known one in steel works, and it would be interesting to know the cost of a stoppage to traffic on a railway caused by hot axle-boxes.

Illustrations 7 and 8 illustrate the application of split roller bearings to Colliery Screens of the reciprocating type used for the purpose of dewatering and classifying coal.

Such screens consist essentially of a series of perforated trays inclined at a slight angle and moved backwards and forwards through a distance of about 2", some 250 times a minute.

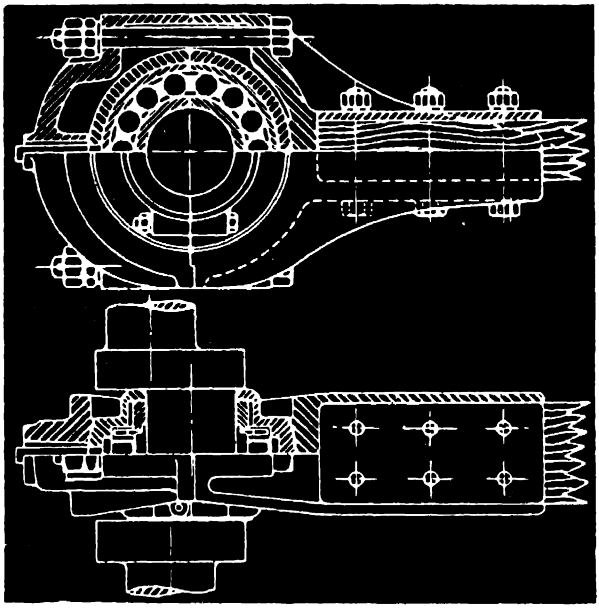
The movement of these trays backwards and forwards gradually shakes the coal down the length of the trays passing successively from one tray to the other. The perforations in the first series of trays are small so that as the coal passes down the smaller pieces fall through these small holes into classifying chutes. These perforations gradually become larger along the length of the trays so that larger and larger pieces of coal can fall through into different classifying chutes and the coal is sorted out in the various sizes.

Naturally such screens create a great deal of coal dust and the bearings have to work in a very dusty atmosphere.



No. 7

Illustration No. 7.—The first portion of the trays of the screen is shown in the foreground, these trays are driven by a crank shaft through wooden connecting rods, two connecting rods to each tray and four of these wooden connecting rods, four big end bearings, crank shaft and two crank shaft bearings are clearly visible in the illustration.



No. 8

Illustration No. 8.—Shows the split roller bearings which are used as crank pin bearings for this installation. The crank pins are $4\frac{1}{2}''$ diameter, the crank shaft rotates at a speed of 250 r.p.m. and the thrust from the connecting rod on the bearing amounts to two tons.

The attachment of the wooden connecting rod to the steel connecting rod end, which is made in two halves is clearly shown. This steel connecting rod end is bored spherical to receive the spherical housing containing the split roller bearing so that the connecting rod is free to swivel and thus prevents breakage to wooden connecting rods.

Crank pins obviously offer an ideal application for split roller bearings as the inner races are clamped directly on to the crank pin. Were solid roller bearings used they would have to be much larger, in order to thread over the throws of the crank, and consequently would be expensive.

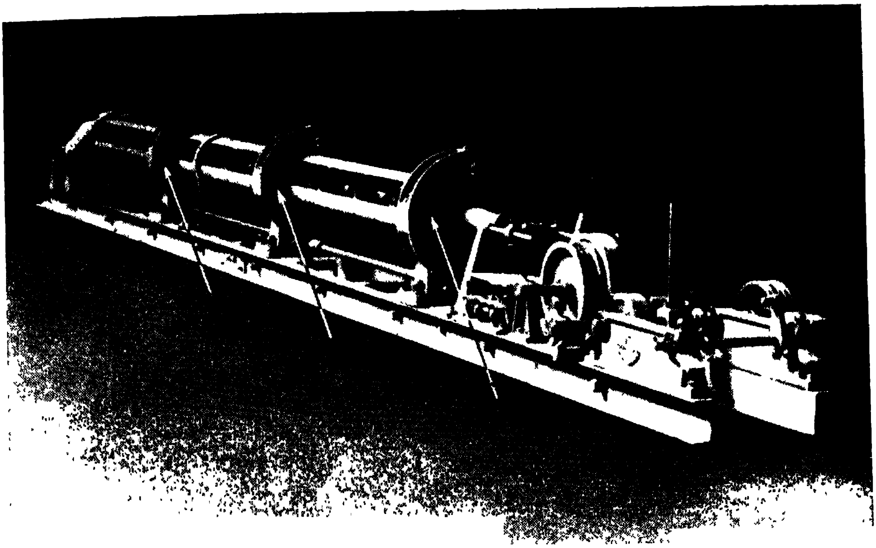
The provision of split roller bearings on such colliery screens has proved so successful that a large number have been fitted to such screens and as described below, this affords a further example of increased production being obtained by avoiding breakdowns and by the ability to run at higher speeds.

Formerly brass bushes were used for such crank pin bearings and it was found that owing to the amount of coal dust in the atmosphere, both the brass bushes and the crank pins themselves wore rapidly, with the result that the screening trays were not moved smoothly backwards and forwards but were violently jerked about owing to the knocking of the big end bearings and shaken to pieces, the rivets in the screen bodies were liable to become loose or where welded, the welded parts to give way.

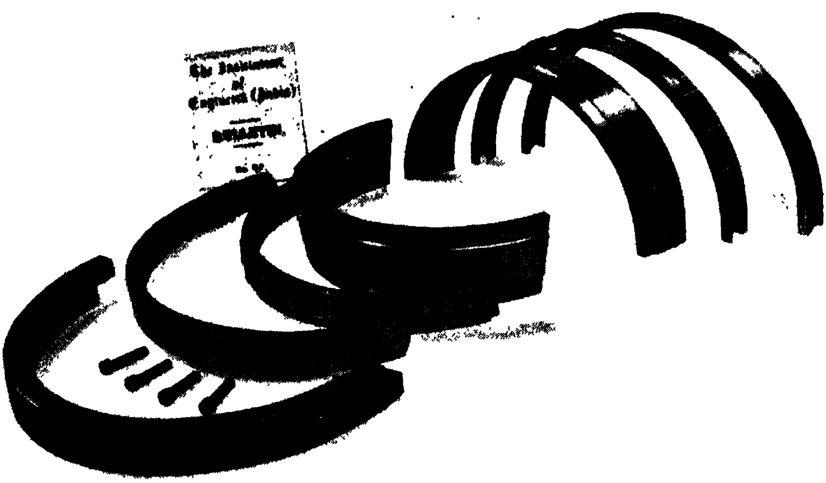
To obviate this as far as possible screens driven by brass big end bearings were run at relatively low speeds, they had to be frequently stopped for truing up of crank pins and brass bushes and for the repair of the screen trays themselves which had been damaged owing to the jerking they received, all of which caused reduction in output.

The application of split roller bearings has cured all this trouble. Arrangements are made to exclude the coal dust from the roller bearings which in themselves do not wear, the hardened steel inner races protect the crank pins from wear, and consequently there is no shock load on the screen bodies, so that they do not suffer damage and the constant maintenance work and the replacement of crank shafts has and is being avoided. A frequent source of trouble in the past has been broken connecting rods, which has also been avoided so that interruptions to production, due to the necessity of maintenance work no longer occur and increased production is obtained.

Furthermore the split roller bearing crank pin bearings have been found to work so well that the speed of the crank shaft and consequently the speed of the screens has been materially increased. More modern screening plants are being run at crank shaft speeds up to 350 r.p.m. with consequent increased output.



No. 9



No. 10

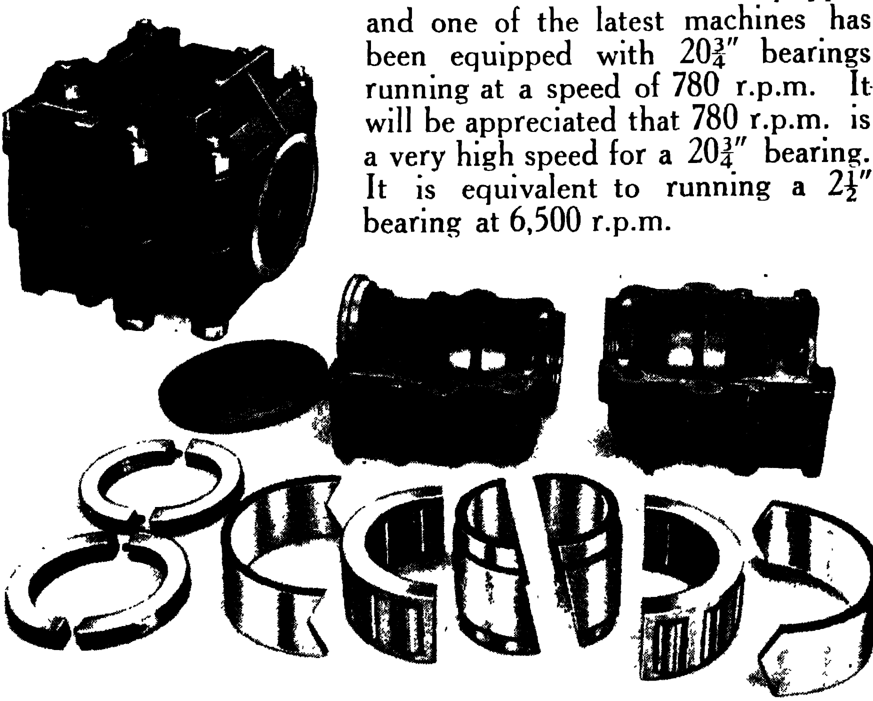
Illustrations Nos. 9 *and* 10—Show the application of split roller bearings to a high speed strander, a machine which is used for the manufacture of wire rope or electric cables. An

essential feature of the machine is the rotating tube shown on the left hand side of the illustration. This tube carries the bobbins of wire which are spun or twisted together by the rotation of the tube and form the cable. The tube in this machine runs at a speed of 1,000 r.p.m. and is carried in three $17\frac{1}{2}''$ split roller bearings as are shown in illustration No. 10 and which surround the tube as can be seen in illustration No. 9.

Formerly the tubes of such cable stranding machines were carried on small rollers which set up a good deal of vibration and were very noisy, so that the speed of such a cable stranding machine was very definitely limited by the vibration.

The application of large split roller bearings surrounding the tube has definitely put a stop to all vibration, it has converted what was previously a very noisy machine into a quiet machine, and has enabled the speed to be increased by some 25 per cent which has given a corresponding increase in production.

The application of such split roller bearings to cable stranding machinery has proved so successful that a great many such machines have been so equipped and one of the latest machines has been equipped with $20\frac{3}{4}''$ bearings running at a speed of 780 r.p.m. It will be appreciated that 780 r.p.m. is a very high speed for a $20\frac{3}{4}''$ bearing. It is equivalent to running a $2\frac{1}{2}''$ bearing at 6,500 r.p.m.



No. 11

Illustration No. 11—Shows a split roller bearing railway axle-box with the internal parts laid out alongside, from which the split inner race with the joint at an angle, will be easily recognised. The two halves of the cage containing the rollers, the two halves of the outer race and the clamping rings for clamping the inner race on to the journal are also clearly seen.

This illustration is of particular interest in India as it shows one of a large number of split roller bearing axle-boxes which have been supplied to the H. H. Gaekwar of Baroda State Railway for their rail cars, metre gauge and narrow gauge rolling stock.

When the Author had the privilege of addressing the Institution of Engineers (India) in Calcutta and Bombay, he was able to show some forty lantern slides and so had an opportunity of illustrating and describing a great many more industrial applications, but for the purpose of printing in the journal, the illustrations are necessarily limited by space to eleven, and descriptions without the illustrations are relatively uninteresting so that he can only briefly mention applications to Diesel engines, steam engines, propeller shafting on board ship, to tea machinery, flour mill machinery, jute machinery, cotton machinery, and so forth, but to all of which the principles brought out in the description and the illustrations in the foregoing paper apply.

In conclusion the Author desires to express his thanks to the Cooper Roller Bearings Co. Ltd., and to several others for their kind permission to use many of the illustrations shown in this paper.

SANITARY ENGINEERING IN BOMBAY PRESIDENCY

BY

DIWAN BAHADUR V. G. SHETE.

(Not an Institution paper but read at the Bombay Centre).

Gentlemen,

During this fortnight you had occasion to hear on two occasions on the subject of Sanitary Engineering or Public Health Works. One was in the address given by Mr. Modak at the time of his address at the general meeting of the Bombay Engineering Congress and the other was in the lecture by Prof. Ghosh on Friday last. To-day I am to give you a talk on Sanitary Engineering in Bombay Presidency. This, I propose to do, by giving you the progress of works in Sanitary Engineering from administrative, financial and technical point of view.

The necessity of major Public Health Works of water supply and drainage is felt more and more as population gets congregated in townships and cities. The location of towns and cities is primarily governed by the requirements of the people in securing advantageous positions for their industries, grouping for natural products and their trade for political considerations, etc., and public health works are mostly required to be fitted in afterwards. Hence the difficulties of the Health Engineer to devise schemes suited to the localities developing or developed. The provision of good and safe water supply and drainage facilities are two of the vital necessities of life and these can never be left in the background for any length of time or *sine die.* Their provision is an indirect insurance of life and any taxes levied or proposed to be levied for meeting the cost of such works is practically an insurance premium payable to the local body annually for ensuring a collective effect on the good health of the town as a whole.

These works are mostly dependent on the financial and administrative considerations and it is only the matter of technical details that is left to the Engineer to be decided upon consistent with the financial capacity of the local body required to undertake such work. They have nevertheless to take a reasonably long view of anticipated future requirements in making provisions for these works.

Such works being of local utility, local bodies are charged to provide for them as part of their obligatory duties. These bodies were brought into existence in the fifties or sixties of the last century and since then each one has tried in its own way to make provision for these works as suited their pockets. The revenue officers with the advice of Sanitary Commissioners of those days were exclusively giving advice for these works and the Sanitary Commissioner being only primarily a medical man, the Sanitary Engineer was brought on the stage in 1892 when also the Sanitary Board was formed to give advice and assistance to the Local Boards and District Municipalities and to all departments of Government in matters affecting Public Health. This Board was constituted with the Sanitary Commissioner and the Sanitary Engineer as its first two members. The rules of Sanitary Board as then constituted, laid down as its four main functions, *viz.*:—

(1) Selection and layout of new sites for station and new bazaars,

(2) Preparation of schemes for sanitary works required to improve the health, comfort, and convenience of the people,

(3) Examination of any plans for sanitary works which may be submitted for their opinion,

(4) Inspection of sites for sanitary works projected and inspection of sanitary works in progress.

These rules were further revised in 1903, 1913 and 1917 and the Sanitary Engineer, thereafter called the Superintending Engineer, Public Health, was authorized to take up the construction works also, in addition to his advisory capacity.

Two more members were added to the Sanitary Board in the year 1902 (*viz.*, Commissioner, Central Division, and the Chief Engineer, Public Works Department), and in 1903 Surgeon-General to Government was added and made the President of

that Board. In 1913 the Commissioner, Central Division, was made the President dropping out the Surgeon-General, and the Secretary to Government, General Department, and one non-official member (Diwan Bahadur K. R. Godbole) were added as two more members. In 1931 a second non-official member was added and later on the consulting surveyor to Government was added to the Board and the Board's name changed to Board of Public Health Works. The Board to-day consists of one President, 4 officials, 2 non-officials selected from legislative assembly members and one official, the Consulting Public Health Engineer as member and secretary, in all eight.

The duties of Sanitary Engineer up to about 1910 were almost entirely of advisory nature except for one work, Pandharpur W.S., which work was undertaken by Government for the benefit of pilgrims at entire Government cost and under the direct control of the Sanitary Engineer. The effect of this change of duty led to the further expansion of the Sanitary Board and later on the preparation of sanitary projects was made an essential part of the Sanitary Engineer's duties. After 1920 the Sanitary Engineer was entrusted with the construction of major Public Health Works in preference to the P. W. D. Agency but the reorganization scheme of 1931 reversed the position and brought his duties back to advisory or consultant stage only.

Major Public Health Works essentially require large funds for their execution and subsequent maintenance and cannot be undertaken from only the annual savings of a local body. Financial help from Government was first given by the Government of India to the extent of nearly 10 lakhs of rupees for a fixed number of years from which Government of Bombay used to give grants in aid to local bodies to the extent of 50% of the estimated cost of works. Government of India's grants were subsequently stopped but Government of Bombay continued to give similar grants till about the year 1923 after which they curtailed them except for previous promises and brought them down to the extent of full centage charges (24% up to 1927 and 28% thereafter) leviable for construction by Government agency. Plans and estimates were authorized to be drawn up by Superintending Engineer, Public Health, free of charge to the local body, and half remission of establishment and tools and plants charges for construction in the case of water-works, and whole remission in the case of drainage works was available till about the year

1931. As a further aid loans at low rates of interest repayable in fixed number of years for balance of cost was also granted by Government.

The progress of works when 50% grants were obtainable was very fast as also when full centage charges were available and during that period the Sanitary Engineer's branch was actually carrying out works to the extent of 10 to 16 lakhs of rupees annually and projects were kept ready or under consideration for a total programme of nearly 100 lakhs.

The reorganization scheme of 1931 which was mainly put forward for curtailment of expenditure in the P. W. D., of which the Sanitary Engineer's branch was and is a part, hit the Sanitary Engineer's branch very hard, and altogether changed the whole aspect of the progress of these works. The design and construction of Public Health Works was merged in the ordinary duties of the local Executive Engineers of Divisions and the Sanitary Engineer, who was all along from 1892 to 1931 an officer of the Superintending Engineer's grade, had his status reduced from that of Superintending Engineer, to that of an Executive Engineer, although he is even to-day called an administrative officer.

Financially Government are now offering no help except for preliminary investigation and preliminary report but are on the contrary charging the local bodies,

(a) for preparation of projects, $2\frac{1}{2}\%$ of the estimated cost of works;

(b) for scrutiny of projects, if these are prepared by any outside agency, $1\frac{1}{4}\%$;

(c) for inspection by consulting Public Health Engineer during construction, $1\frac{1}{4}\%$;

and (d) for construction of works by Government agency, 15%.

It will thus be seen that all help from Government in any form is now withdrawn and the local bodies are required to pay for services of Government agency practically in all stages of the scheme. Also the grant of loan from Government is also stopped and the local bodies are required to raise their loans in open market after sanction by Government. It is now inevitable that local bodies must stand on their own legs and arrange

for financing these large schemes by their own efforts to raise fresh taxation in whatever form it may be possible to do so. The report of financing the Surat drainage scheme recently appearing in newspapers is a case in point.

Looking from technical point of view each town or city has its own limitations for drawing up a scheme suited to its location, geographical position and its general configuration. The broad outline of one scheme cannot be applicable to another. The different sources of water supply for head works will require diversity of schemes for different towns and similarly the drainage disposal works will be different for each town according to the natural facilities for outfall available.

An analysis of the Public Health Works constructed so far in the Bombay Presidency shows that out of 130 municipalities in the presidency proper in 1937, having a total population of 26½ lakhs of people, water-works on piped water supply system are constructed in 25 municipalities having a total population of 13⅓ lakhs (nearly half of the urban population), of these 25, only three municipalities (Ahmedabad, Poona City and Kapadwanj) have got sewerage systems with outfall disposal works and 2 more (Pandhapur and Sholapur) have got partial schemes constructed. Of the 25 waterworks, 16 have got pumping installation and the rest 9 are gravitation schemes. Naturally filtered water (through infiltration galleries) is available at 7 places while artificially filtered water is available at 6 places, the rest 12 places getting their supplies from natural sources direct with or without chlorination.

Of the three drainage schemes in operation, disposal of sewage at Ahmedabad is partly by crude sewage irrigation on broad irrigation principle and partly by intermittent downward filtration through sand-mixed alluvial soil recently introduced. Disposal of sewage at Poona is by broad irrigation over an area of about 1,500 acres annually irrigated for sugarcane crop, but the crude sewage is here diluted with Mutha Canal water so as to give a dose of 300 to 600 lbs. of nitrogen as manure per each acre of crop of sugarcane; at Kapadwanj the crude sewage is simply passed through a settling tank and its effluent is given for irrigation of crops on the area adjoining the settling tank.

Two more drainage schemes are in course of construction, *viz.*, Bandra and Kurla in the suburbs of Bombay. Bandra includes drainage of Khar and Santa Cruz areas and there will be a common outfall and disposal works for these three localities. The method of disposal will be at first by continuous flow settling tanks and will eventually be followed by activated sludge process when found necessary.

In almost all the Public Health Works there is no last word said, once the works undertaken, are completed. As soon as these works are brought into operation, the facilities provided give rise to early growth of population with increase in the rate of consumption per head of population.

In the schemes prepared before 1910, it was the practice (and the people were content) to provide for a supply of only 10 gallons per head which, now will be called nothing short of a silly provision. The rate of consumption has now reached a figure of 25 to 30 gallons in non-drained or partially drained towns on surface drainage system and a figure of 50 to 55 gallons a head for towns provided with underground drainage system. With industrial towns it is still more the case and such increases are necessarily required to be catered for. Thus Public Health Works require to be constantly enlarged. Further, if in initial stages of these schemes, only partial provisions are made these prove to be very disappointing and even detrimental as soon as the works are brought into operation. In this connection I may mention the case of Poona drainage for which a partial scheme was prepared in 1910 and constructed during the years 1911-1916. The provision made therein was for a population of 1 lakh with 10 gallons of sewage per head per day, a total quantity of 10 lakhs per day. During the very first year of its operation, *i.e.*, in 1916 it was found that the daily quantity received at the pumping station was nearly treble of the provision made and that the quantity in excess of the provision had to be overflowed through the adjoining town *nala* into the Mutha river. Imagine what the effect on the health of the people residing in the vicinity of *nala* and river must have been. The same is the case with water supply provisions. If water supply schemes are made even on the basis of 30 gallons per head at the present time, with full drainage facility, in the town, nothing short of 50 gallons per head is likely to be the consumption unless the supplies are thoroughly metered. The

source of supply is thus overtaxed and if it is not adequate to cope with the increased demand, there is the only alternative left, of having to resort to curtailment of the supply by restricting the hours of consumption.

This shows the importance of keeping the existing works abreast of the times and requirements and unless they are constantly added to or extended far in advance of the creation of demand, they become a constant source of complaints from those who are paying for the commodity. Apart from selection of sources of supply in waterworks and decisions regarding methods of disposal to be adopted in particular cases, there is a great deal of foresight and thought required to be given in designing a good, efficient, and economical system of distribution for waterworks, or collection system in the case of drainage, and even after the proper works, as designed, are constructed, their behaviour under varying conditions of demand has to be noted from year to year, so that any deficiencies brought to light in actual practice can be remedied by providing additional works well in advance. The statistical details maintained, both financial and technical, afford a good guide for further steps to be taken. It is therefore very desirable that complete reports of the working of all Public Health Works in each Presidency or Province should be made out annually and made available by publishing them. Such information is available from United Provinces. In Bombay Presidency a start has been made since last year to publish the statistical records in the annual reports of the Sanitary Board. In achieving this, great effort had to be made in getting out correct figures from the local bodies, whose annual reports contained generally special reports of the Health Department and School Boards, but nothing for the Municipal Engineering Works, nor anything for Public Health Works.

In many cases I have found that the local bodies prefer to spread the construction of Public Health Works over a number of years, to enable them to meet the costs from their annual savings. This is a very short-sighted policy. It is questionable whether it is a sound policy from health point of view. In fact the construction of partial works, for one part of the town, gives advantage to the people residing in that locality over other residents in other parts of the town and these latter have therefore

to face the disadvantages for no fault of their own and probably for an indefinite period, extending over, may be, for a generation or so. The health of one set of people is not to be sacrificed for the sake of financial incapacity. If the necessity of a full scheme is established and provision for its construction is required to be made, its construction should be completed in as short a time as possible, so that all residents may enjoy the benefits of the scheme equally and uniformly. There should be therefore a bold policy adopted both in the design of works and their quick construction. The utility of their works is not only available to the present generation but also to the future generations and therefore it is quite in order, and more desirable, that the financial burden of the scheme is borne by both the present and future generations, also by arranging for funds to be raised by loans repayable in long periods.

Coming to the question of quality of water supply I have stated earlier in this talk, we have very few towns in this Presidency supplied with filtered water and the rest of the towns are left to the mercies of Nature. It is only in Poona Cantonment Water Works that a really good and safe water is available and it is tested from day to day in a Public Health Laboratory close to their works. In this case there is a military watch throughout the year.

In other places, where the filters are provided, they are of the slow-sand type except for Hubli and are either working inefficiently or their sizes are insufficient to deal with the daily consumption quantity. In the last few years a system of water analysis has been introduced and samples are analysed for every change of season or in some cases every month to keep a record of what is issued to the people of the town. If these samples disclose any bad quality it is to be reported to the Board of Public Health Works for taking such action as may be considered necessary.

Improvements in this direction cannot however be made compulsory under the existing municipal law, nor is there any way by which the drainage liquids can be compulsorily made to be treated to obtain certain standard of purity before their discharge into natural streams. There is no Public Health Act for either this province or for the whole of India and the result of such non-legislature is to make the people of areas residing in

the downstream portions suffer for dilatoriness of the upstream towns in providing proper works for purification. In this connection I might once again quote the instance of Poona drainage. The Poona river (called Mutha) used to receive, prior to the introduction of the present system of sewerage, only sullage water, which though harmful, was not seriously affecting the health of the people downstream of Poona due to its large dilution in the great pool of water formed in this river bed by a bund some three miles downstream of old outfall. After the introduction of the Sewage Scheme there was overflow from the drainage pumping station and the liquid given out was real sewage. This not only spoiled the pool of water but its effect was felt, over a length of nearly twelve miles downstream, and it could not be made compulsory on the local bodies to make prompt arrangements to remove the nuisance. However as the Poona city had already launched the scheme, improvement works were undertaken and in a course of few years, the overflows were stopped. But the other local bodies round about Poona had done nothing to stop the dirty liquids discharged from their own areas through the city limits. Even now the state of affairs is the same and when the question of compulsion was raised and legal proceedings threatened, arguments were put forward that neither the city municipality nor Government can compel these other bodies to stop the practices of passing the dirty liquids through city limits as they had the right of some 150 years or so. Well, this is a case in which one body spends lakhs of rupees to make its area sanitary and free from nuisance, while the other body is on the fence to retain the nuisance as long as it pleases. The Public Health Act, which not only deals with the preventible or infectious diseases but with nuisances and river pollutions for which Engineering Works are required, is essentially required to prevent any persistence of rights to make or to retain nuisance of the above nature. Our province is I think far behind the times in this matter and I hope the authorities concerned will take early action to introduce such an Act. Madras has recently introduced their Public Health Bill but I do not know whether it is an all-embracing Act on the lines of the Public Health Act of England of 1936, which has consolidated all other minor Acts affecting Public Health. Probably such an Act will require to be an all-India one, to settle disputes if any, between the Provinces wherever they may arise on their borders.

The Public Health Engineer has to deal not only with major Public Health Works but also with the internal drainage of large public buildings, the standard of fittings provided therein and their testing, etc. Large buildings in big cities are provided for offices, business premises, hospitals, banks where the floating population may be from 200 to 2,000 or even more. The design of such buildings has to conform to the layout of its sanitary provisions and if such buildings are in a busy quarter of a town, there are limitations to the provisions of sanitary annexes and their connections to the main drainage system. The internal drainage is as important as public drainage, requiring the soil pipe system, waste water system, rain water system to be properly arranged along with the air conditioning and hot and cold water supply systems. The fixing of these fittings is a licensed plumber's job, and these have to be ultimately passed by the municipal engineer before occupation of the building. The municipal bye-laws may or may not provide for such licences, and in their absence, work is done through any local plumbers. I do not think that peculiar idiosyncracies of the makers of fittings, or the owners of property, getting such fittings fixed by unlicensed plumbers, should be encouraged and in any town where an underground system of drainage is to be introduced, the bye-laws for sanitary fittings, their specification and methods of fixing up and etc., should be completely made out and put in the statute, before the completion of main drainage system. There should be no slackness in enforcing the bye-laws and there should be no substitute allowed on any account. I might quote the instances of Ahmedabad and again of Poona where the flushing cisterns attached to water closets are in many houses dispensed with, and direct W. S. connections controlled by wheel valves, or weight cocks, are fitted to serve the purpose of flushing cisterns. This results in much waste of water without giving the full effect of flushing that is so essential for the efficient working of the system. In one case I had to inspect a house where the owner had stated that he had introduced a flushing water closet. I found that the water closet was without its trap or flushing cistern but that he had only provided a pan of modern type and joined it to vertical stoneware pipe discharging into a drain at its bottom on the ground floor. Such a closet was in use for about a year with water poured by hand after use. The owner had taken pride in telling his friends in the vicinity that he had taken advantage of the new system by

providing a water closet of the above nature and abolished his old privy method. These substitutes are faulty and abhorrent and therefore strict observance and exercise of whatever bye-laws are made, are therefore a matter of greatest importance in the operation of the system as a whole.

I have so far dealt with the progress of Public Health Works in major towns and municipalities. The question cannot be left there alone. We have a very large population residing in the villages which are under the control of the District Local Boards. For purposes of sanitary works, villages are practically left to themselves. Occasional monetary help is given by the District Local Boards for providing sources of water supply and that too is partial, *i.e.*, ⅓rd cost to be provided by villagers themselves and ⅔rds provided by the Boards, of which ⅓rd may be Government grant. The source of supply is usually a river or local *nala* in which surface ditches are dug up and left either protected by masonry or unprotected, and local wells built by Local Boards and private wells. In many cases people have to go to long distances to fetch their supplies from wells or rivers outside the village. The present Government have made it their policy to make liberal grants to provide new wells where they are non-existent and to provide communicating roads to all villages in the Province. For distributions of these grants, local committees under the chairmanship of Collectors of districts have been formed and the executive authority for construction is the Local Board. The design and location of wells is a matter which must require careful attention so that money may not be wasted by wrong locations. Much therefore rests on the integrity of the Local Board Engineer on whom would rest the final responsibility for efficiency of the village wells. It is to be hoped that the new Rural Development Department would arrange to get the best results by proper supervision, before and after any works are undertaken and completed. From Public Health point of view enactment is also required to prevent their contamination or wrong use. I know of a case in point in which a village well used for drinking purposes and privately owned, cannot be protected from contamination due to the persistence of the owner in not allowing any alteration to be made to its stepping. There is no other well in that village belonging to the District Local Board who alone can put a restriction for prevention of contamination. This

well being a stepped one is constantly a source of guinea-worm disease. Its conversion into a draw well, would remove the danger of the disease. When however the owner was approached to make the necessary conversion even at the cost of villagers or the District Local Board, he refused to do so under the fear that his proprietary right over the well would be restricted and that the District Local Board would appropriate the well with only a small expenditure and make it useful for all the communities in the village, which is resented by even the villagers themselves. On the other hand the villagers cannot be prevented from using the well as they consider the supply satisfactory compared to other wells in the vicinity and safe from any communal interference, with the result that they apparently prefer disease to communal interference. Such cases cannot be dealt with by existing law except under Acquisition Act. With the growth of wells now sought to be provided for each village it may be desirable to include such provisions in Public Health Act as would make it compulsory to make the required changes to private property wherever absolutely necessary and thus to achieve the desired protection.

Gentlemen, I have given you a small resumé of what has been the progress of Sanitary Engineering and how it was achieved during the last 40 years or so, even under the vagaries and vacillations of Government policy with regard to financial help. I have avoided of course any talk on technical side of the works as regards the standards of purity both for water supply or drainage disposal works. These, I think, should be fixed up by research work and practical consideration of local conditions applicable to India and no blind following of European standards should be attempted. There should be general standards and particular deviations from these are permissible for particular localities, where sea outfalls or dilution methods of disposal are necessary. Statistical records of operation and maintenance of works offer a good guide and I advocate that these must always be maintained by the Engineers in charge and embodied in the annual reports of the local bodies. Consolidated reports for the province as a whole, can be and should be made up as is done in Europe and America.

I am hopeful that a time will come in India when water works association and sewage purification association will be formed in India and will play a great part in improving the sanitary condition of India, both urban and rural, with the help of Public Health Act.

TUBE WELL IRRIGATION AND ITS POSSIBILITIES

BY

MR. A. N. MITRA, M.A., M.I.E. (Ind.)

(Not an Institution paper, but read at the Bengal Centre).

Introductory.— From the earliest times to the present day, Irrigation has been found necessary all over the world, to supplement seasonal rainfall, which is often found either insufficient for the growth of crops or inopportune. With the increase of population, the demand for Irrigation is everywhere on the increase. The two main systems of Irrigation are :—

(1) By Flow.
(2) By Lift.

The first one serves very large tracts of country at the same time and means the bringing of rivers into use, whereas the second system makes use of tanks and wells, and generally serves small areas. In the first system, cuts in River Banks, Dams, Weirs and Barrages across rivers are used to raise river levels and divert the waters into the country for Irrigation. In the second system, the Donga, the Mote, the Bucket, the Persian Wheel, etc., are used by man and bullock or other animal power.

The use of this type of power for lifting water is bound to be less efficient than the use of machinery. Hence Oil Engines came into use some 50 years back in India to pump water from tanks and wells, and was largely used in Madras. The biggest system in use there is the Divi Island Pumping Scheme, where the water from the Kistna River is pumped into one of the Islands of the Kistna Delta and irrigates some 50,000 acres.

Tube Wells.—It is possible however to make Lift Irrigation too, to benefit large areas. In this paper I mean to describe a system of Well Irrigation that is being practised in the United

Provinces on a large scale, *viz.*, Irrigation from Tube Wells. It may be possible to use ordinary wells for the purpose, but a tube well has got greater possibilities as it can be driven much deeper than the ordinary well. The power used in this case is Hydro-electricity.

Power from Canal Falls.—In the Upper Ganges Canal which was constructed in the middle of the last century and runs for 300 miles from Hardwar to Cawnpore—there are some 12 falls between mile 5 and mile 163. In the Table below are given the details of the falls and the power available.

No.	Fall.	Mileage from Hardwar.	Minimum Head.	Cold Weather (Cusecs) Discharge.	Total Capacity in Kilowatts.
1.	Ranipore ..	5	12·0	5,000	3,934
2.	Bahadurabad & Salempore	7	15·5	5,000	5,082
3.	Pathri ..	10	10·0	5,000	3,280
4.	Asafnagar ..	23	10·0	4,000	2,623
5.	Mahmudpur ..	31	15·5	4,000	4,066
6.	Nirgajni ..	43	15·5	4,000	4,066
7.	Chitaura ..	56	15·5	3,000	3,049
8.	Salawa ..	67	15·5	3,000	3,049
9.	Bhola ..	84	12·0	3,000	2,700
10.	Palra ..	148	9·0	1,200	708
11.	Sumera ..	163	15·5	1,200	1,219
					33,776 kW
					Say 34,000 kW.

Scope of Project.—The total power available is 34,000 kilowatts. The biggest station Bahadurabad has a capacity of 5,000 and the smallest Palra, one of 700 kW. About 5 lacs of Rupees were spent in Reconnaissance Surveys and the work started about the year 1920. Originally a small Power Station was installed at Bahadurabad to supply power for construction of permanent Head Works for the Ganges Canal at Hardwar about 1926. Later on, the scheme for supply of Hydro-electric

power on a large scale materialised and it is to benefit eight districts on the western part of the United Provinces. The power generated is to be used and is being already used partially for lighting and supplying power for large and small industries as Cotton, Sugar, Flour Mills in 88 towns, lighting Railway Stations, pumping water for Irrigation from the Ramganga and the Kalinadi and lastly for supply of power for pumping water from tube wells for irrigation of tracts where flow irrigation has not been found possible.

The Grid.—The Districts under the operation of the Hydro-electric systems are Saharanpore, Bijnor, Moradabad, Budaon, Muzaffarnagar, Meerut, Bulandshahr and Aligarh, and it is called the Hydro-electric *Grid*, being covered by the electric lines; the system also supplies power to an industrial concern at Dayalbagh, Agra.

The actual work started about 1929 and by now about one-third of the power has been made available ; the scheme will be gradually worked up and brought into full operation by about 1950.

Power Houses.—The power houses have generally been built over the falls themselves to economise cost. Generally there were 4 bays of 54′ each. These were subdivided into 8 by constructing piers in between and ½ the space utilised for power house and power supply. The remaining half would be used according to demand later on. In some places falls have been increased to 19′ for better power supply.

Generators.—For the present 4 turbo alternators of 600 kW capacity have been installed at Bahadurabad giving an output of power of 2,400 kW with head 15′/19′. The ultimate development of power would be 5,400 kW, vertical shaft propeller Type Turbines have been used for 3, and Kaplan Type for the 4th bay. The Turbines are connected to 3-phase 50 cycle 750 kVA alternators at 6,600 volts. Each turbine takes 600 cusecs at maximum discharge of 1,000 cusecs per bay of 8 bays. The balance of 400 cusecs has to be escaped by automatic gates provided in the downstream wall of the pits. These gates (Boving type) act perfectly automatically for 400 cusecs or for the whole supply of 1,000 cusecs in case of a sudden shutting down of the machines.

Transmission.—The main transmission lines take the alternating current at 66,000 and 37,000 volts (some 592 miles). The branch lines (some 444 miles) take the current at 11,000 volts. For running motors for industries and tube wells 440 volts are used. Many of the transformers are of the outdoor type. Rivers are crossed by lattice type towers. The posts are generally of steel though wooden posts are in use in some rural lines.

Scope of Tube Wells.—For the tube wells the proposal for ultimate development is for 1,500 of them to be constructed by the State and distributed as below :—

Bijnor District	..	137	East of Ganges.
Moradabad District	..	429	
Budaon District	..	396	
Muzaffarnagar District	..	62	West of Ganges.
Meerut District	..	220	
Bulandshahr District	..	154	
Aligarh District	..	44	
Total	..	1,442	

The distribution has been made according to the area to be irrigated and also with a view to the easy possibility of tapping water. The total area to be benefited is 2,900 sq. miles.

Command.—It has been found by experiment that a well supplying 1·5 cusecs or 1,29,600 cft. per day (33,000 gallons per hour) gives the best results. They command about 1,000 to 1,200 acres and are placed $1\frac{1}{2}$ miles apart. The commanded area is about 2 sq. miles.

Taking 4″ of water on the field required for wheat (or 88,000 gallons per acre) and as wheat requires watering for 40 days (15th November to 24th December) and taking the tube well to work for 22 hours daily, the maximum area irrigable under wheat is—$\frac{40 \times 22 \times 33,000}{88,000} = 330$ acres. Sugarcane requires 5″ water on the field (*i.e.*, 110,000 gallons per acre) and requires watering every 21 days.

Maximum area irrigable under sugarcane $= \dfrac{21 \times 24 \times 33{,}000}{110{,}000}$ $= 151$ acres. These are the principal crops irrigated. Calculations for other crops may be made on the above basis.

The tract that would benefit from tube well irrigation is expected to grow the following acreage of crops :

Rabi	..	482,000 acres.
Sugarcane	..	183,000 „
Other Kharif	..	88,000 „
Total	..	753,000 acres.

Description of Well.—The tube well 8″ diameter is driven to a depth of about 240′. The following classes of soils are met with—stoney, clay, medium clay, fine, medium and coarse sand. The tract in question lies between the Jumna and the Ganges and between the Ganges and the Ramganga in the U.P., the rivers flowing from north to south and south-east. In the northern part of this tract, gravel merging into coarse sand predominates in the soil with a small quantity of clay, as in Bijnor, Moradabad, Meerut and Budaon Districts. Here the tube wells are most successful. In the southern parts of the area as in Aligarh, south Budaon and Bulandshahr, the sub-soil contains more clay and the yield of water is less.

Strainers.—In an average type well, out of 240′ bored, about 90′ is found to consist of coarse sands, which form the water-bearing strata and occur in separate layers with layers of clay interspersed between them. Instead of putting one length of strainer at the extreme end of the well, strainers are placed wherever the water-bearing strata, medium and coarse sand are found, hence about 90′ length of strainers are put in ; the remaining 150′ (about), where clay and fine sands occur, are constructed with Hume Cement Concrete Pipes.

The strainer is 8″ diameter pipe with 1″ diameter holes placed 3″ apart. Over that thin copper sheet with 144 slits to the sq. in. is wound very closely. Of strainers, the "Tej" type is found to be the best and costs 10/- per sft. Another, the "Agricultural Type" costs 20/- sft. Many strainers generally come within 50′ of the bottom and some above that level.

Pumps.—Generally horizontal centrifugal pumps are used with $12\frac{1}{2}$ H.P. Electric Motors. Where the spring level is 40′ below ground level or more, vertical pumps of the "bore-hole" type are used. 10″ to 13″ of casing pipes are used for 35′.

Usually the spring level is 20′ below G. L.	..	20′
Working depression including Friction	..	18′
Command required above Ground Level	..	2′
Total working head	..	40′

Taking average overall efficiency of pumping sets = 61%,

$$\text{Energy consumed per hour} = \frac{40 \times 1{\cdot}5 \times 62{\cdot}5}{550} \times \frac{100 \times {\cdot}746}{61}$$

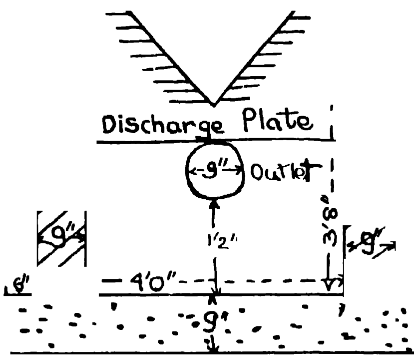
$$= 8{\cdot}25 \text{ units or 9 units per hour.}$$

The suction pipe is reduced from 8″ to 5″ and the delivery pipe increased from 4″ to 6″ diameter.

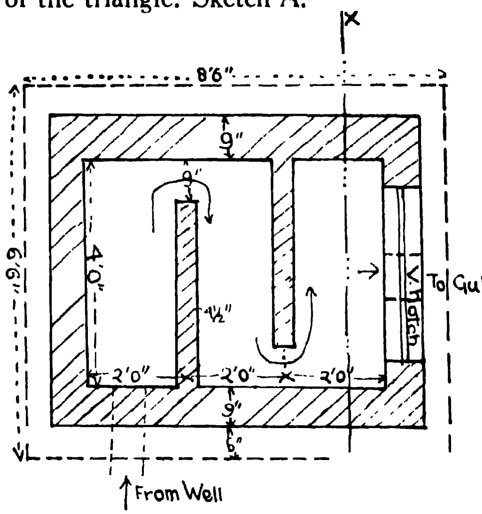
Construction.—The pump and motor are housed in a cylindrical masonry well 7′ diameter. On the top of this a cylindrical room rises 8′ above ground level. This room contains the switch-board with electrical fittings, meters, etc., and a notice board, and can be entered by means of a $6\frac{1}{2}' \times 3'$ door. The room has a R.B. Roof on a steel joist and a salwood floor with an opening through which the pump and motor can be reached some 25′ below. A vertical iron ladder, generally used in ships for going down to the Engine room from the deck is used. The pump and motor are placed at the dry weather spring level with the foot valve 3′ below spring level to avoid pumping difficulties. They are placed on a brick pedestal about 4′ high and the well chamber below the pedestal is floored with 2′ thick concrete through which the tube-well passes down. The well portion is constructed as such, with a cement concrete curb at the bottom. The lowest part of the chamber about 13′ deep has got walls $1\frac{1}{2}$ bricks or $13\frac{1}{2}''$ thick; the remainder 9″ or 1 brick, all done in 1st class bricks and cement mortar.

Measurement.—Outside the Chamber is the gauging tank with a V-notch. Water from delivery pipe enters the tank $6' \times 4' \times 5'$ high. Two walls $4\frac{1}{2}''$ thick are placed to kill the waves

before water passes through the V-notch. Against the notch a steel plate $\frac{1}{8}''$ thick is placed with inches marked on one side and gallons on the other side of the triangle. Sketch A.

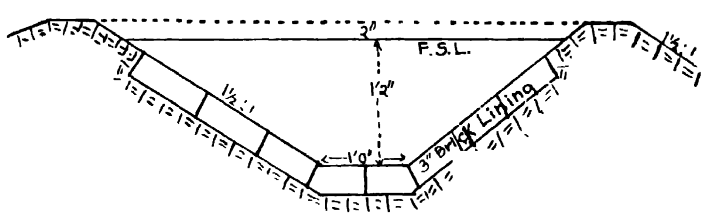


A. Gauging Tank
Elevation on XY.
Scale 2' = 1"



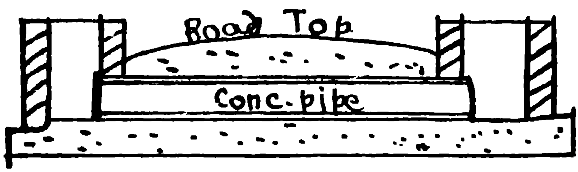
A. Gauging Tank
PLAN.
Scale 2'-1"

Distribution.—After passing through the Gauging Tank water is passed into the channels for supply to fields. Sometimes earthen channels 1′ wide at the bed and 1′ 6″ high are used. But it is more economical to use channels, lined with bricks laid in ghooting lime and sand, as shown in Sketch B. These channels are locally called "*guls.*" The capacity of the channels is 1½ to 2 cusecs.



B. Section of Bricklined Channel or Gul
Scale 1'=1"

The channels may be 3 or 4 according to requirements. Average length of channels is found to be 2½ miles per well, and they are like miniature distributary channels. They are generally in embankment and rarely in cutting to have proper command over fields. Road crossings are managed by 1″ pipe syphons constructed as in Sketch C.



C. 1′0″ diameter Siphon under Road

With the construction of tube wells, kutcha cyclable roads have been constructed from main and branch roads to tube-wells.

Rated maximum voltage is 550 but actual voltage is 440, transformed, from 11,000 volts of the rural lines, by outdoor transformers. Current consumption is 15 amperes. Efficiency is between 60 and 70%.

Costs.—Appended below are the costs of some of the works and of maintenance per well :—

Cost of Pump and Electric Installation .. Rs. 800/-

Operation room 10′ × 10′ with a verandah 12′ × 8′, constructed within 30′ of well and window facing the well so that the operator can always keep watch. Pucca house with R.B. roof and pucca floor .. Rs. 350/-

Distribution system electrical .. Rs. 1,500/-

Cost of lining channels	..	Rs. 1,800/- per mile.
Cost of Earthwork	..	Rs. 300/- per mile.
Cost of Land (about $1\frac{1}{4}$ acres per mile)	..	Rs. 250/- per mile.
Operator (who is also the salesman) gets a pay of	..	Rs. 15/- per month.
Grease oil, etc., per well per month		Rs. 10/-
Electrical staff—Rs. 2/- per well or One mistri looks after 40 wells (about) and there is one Overseer for the same number of wells.		Rs. 40/- for 20 wells
Cost of boring well including pipes and strainers	..	Rs. 1,750/- per well.

Each Sub-divisional Officer has got 150 wells in his charge and each Executive Engineer 500 wells.

Crops.—The crops usually irrigated are wheat, sugarcane, cotton, maize, bajra, gram, barley, vegetables, and small quantities of tobacco. Paddy irrigation is not encouraged as the quantity of water required is large.

Rates.—The charges per unit are -/2/3 for Kharif and -/1/6 for rabi.

This corresponds to Rs. 2/9/3 for sugarcane, Rs. 2/1/- for rabi, Rs. 3/13/9 for other crops per watering per acre.

With $2\frac{1}{4}$ waterings sugarcane rate = Rs. 18/- (about) and wheat Rs. 10/- to Rs. 8/- per acre.

Corresponding Ganges canal rate is Rs. 5/- for wheat.

Maximum pumping hours come to 4,100 hrs. per year nearly.

Average cost of a well with all charges comes to Rs. 8,600/-.

I do not intend to give a mass of figures but the following may be noted:

	Lacs.	Per well.
Total capital outlay ..	126	8,600/-
Gross Revenue ..	42	2,850/-
Working Expenses ..	29	2,010/-
Depreciation ..	3·2	217/-
Net Revenue ..	9·1	626/-
Interest charges on capital outlay payable to the Govt. of India	5·06	345/-
Net Gain to the Province ..	4·09	280/-

Benefits of Tube Well Irrigation.—(1) The tract of country lying to the west of the Ganges is being irrigated by the Upper and Lower Ganges Canals commanding about 4½ million acres or 7,031 sq. miles. Outside this area to the west of the irrigated area, in between and to east of the Ganges, there lay other large tracts without the benefits of irrigation, whereas a large amount of energy due to falls in the canal were going to waste so long. The application of Hydro-Electricity (abbreviation *Hydel*) has rendered this "byproduct" of canal Irrigation to be usefully utilized for power for local industries, big and small, for lighting and power, for large scale irrigation by pumping and has brought or is bringing another 2,900 sq. miles under the benefits of irrigation.

(2) The wells being situated every 2 miles apart suits the individual small cultivator quite well.

(3) The system is flexible and can be expanded gradually.

(4) Water for Irrigation is available all the year round; hence intensive irrigation and cultivation are possible.

(5) With the tube wells it has become easy to find good drinking water and keep down disease, electric lights and fans in the most out of the way Districts, like Budaon and Bulandshahr; desert areas that depended only on the scanty rainfall for cultivation have been converted into smiling fields full of crops.

(6) All this contributes to the general rural uplift and prosperity of the people.

Disadvantages.—Along with this we may consider the difficulties and disadvantages :—

(1) The system is somewhat more costly than Gravity Irrigation. This however is natural for all kinds of Irrigation by pumping. This system being apart of other kinds of power supply which shows a possibility of paying 7½% on the capital cost after full development, is not bad.

(2) Question may be raised about possible failure of underground water supply. Geologists who examined the soils and areas carefully are optimistic. They do not anticipate any failure.

(3) Choking of the wells by sand may be considered. This is possible; for this the Department have got some "plungers" as they call them. These are sand pumps and remove the choking easily. The usual life of tube wells is taken at 17 years which may be considered somewhat small; but this means putting new Hume Pipes and strainers, after removing old ones. The cost would not be prohibitive.

(4) Question of stoppage of electric supply may be considered. This may be due to :—(a) stoppage of canals for:

(i) silt clearance

(ii) repairs to masonry

(b) accidents to electrical apparatus.

Re. (a) the canal has 3 escapes—

(1) Dhanauri, mile 13—8,000 cusecs or the whole discharge of the canal can be passed into the Ratmau River.

(2) Janvi, mile 87—into the Hindan and Jumna Rivers.

(3) Machua, mile 173—into the Kalinadi River. Silt clearance can thus be effected by sections.

Arrangements can also be made to isolate different bays at the canal power stations and execute repairs. Hopper barges are also used for repairs, *i.e.*, silt clearance under water.

Re: (b)—There are Oil Engine standbys at each power station and also at Chandausi, Moradabad, Saharanpur, Meerut, Tundla, Aligarh and Lhaksar capable of supplying some 5,000 kilowatts.

(5) Although tube wells supply water constantly, they do not possess the fertilizing silt of canal water. Hence manuring of fields would be necessary.

Application to Bengal.—The future of Tube Well Irrigation on this connected or Grid basis cannot be one of failure and can be adopted in other Provinces as well. Let us take the case of this Province. Many tracts here are flooded out during rains, whereas no water is available in the dry season. It often happens that the *Kharif* crop is absolutely wasted. Tube wells in such tracts would be a boon for *Rabi* crops. Then there are the North Bengal tracts where the falls in the Tista and Mahananda, both perennial streams, can be the source of electric power which may change the condition of North Bengal for the better. Next come the comparatively dry Districts of West Midnapore, Bankura, Birbhum which suffer badly for want of water. Tube wells would go a long way to ameliorate their conditions. Hydro-Electric power may not be available, but Diesel Oil Engines may be tried or steam engines may be used. Coal would not be very dear for such tracts. Bengal has got a great source of power in the tides. The tidal range in places goes up to 15′ or 20′. This power can be utilised. With cheap power for pumping not only tube wells, but the existing tanks can be brought into commission. All that has to be done is to cause some tanks in a large number of places declared as State Tanks (like State Tube Wells of the U. P.) clean them and utilise them for Irrigation. The Western Bengal Districts have a large number of such tanks which were used in days gone by for Irrigation. The condition of artificial Irrigation in Bengal is still in the "toddling" stage of an infant. A vigorous policy is required to search all the avenues for the supply and utilization of water for the benefit of Irrigation and of the people. In my paper on Irrigation in Bengal read in April 1933, I pointed out that with intensive Irrigation Bengal could gain 45 crores of rupees in crop value with some 2 crores of additional revenue to the State, per year.

EVALUATION OF DEFLECTION CAUSED BY TRAIN OF MOVING LOADS

BY

Dr. S. R. Sen Gupta, B.Sc., Ph. D. (Glasgow), A.M.I.E. (Ind.) and Mr. Suchit Kumar Ghosh, B.E., A.M.I.E. (Ind.)

(Not an Institution Paper, but read at the Bengal Centre).

Introduction :—It is extremely difficult to find out the maximum deflection at any one particular point on the span of a freely supported beam and to locate the exact point at which the deflection is maximum, due to a train of moving loads. The difficulty lies in the determination of the particular arrangement of loading to give the maximum deflection at any given point, and in finding which of these points will be deflected most. It is found, that any particular arrangement of loading to give maximum bending moment at a given point, does not correspond to that for the maximum deflection of this point. The point at which the bending moment is maximum is not necessarily the point having the grestest possible deflection. A method of treatment is outlined in this paper together with an example.

Theoretical Basis :—It has been shown by one of us elsewhere (See Ref. I) that for a beam simply supported at its ends, the deflection at any point, distant *nl* from one end to a unit load at a distance *x* from the same end is given by

$$\delta = \frac{I}{6EI}\left[\frac{l-x}{l}(nl)^3 + \left\{2lx + 3x^2 - \frac{x^3}{l}\right\}nl - (nl-x)^3\right]$$

where, δ = the deflection at a point distant nl from one end of the span (this end taken as the origin),

l = the span,

x = the distance of a unit load from the origin,

I = the constant moment of inertia of the cross section of the beam,

E = the Young's Modulus.

In other words, the above formula is the equation for the Influence Line for Deflection.

It is to be noted, that the Last term $(nL—x)^3$ is to be omitted altogether if x be greater than L.

The method is to use the above equation of the deflection locus.

Method:—The deflection influence line diagrams are drawn for points 0·4 *l*, 0·45 *l* and for 0·5 *l* (*i.e.*, mid-span). These are shown in figures 1, 2 and 3 respectively. The diagrams for points 0·55 *l* and 0·6 *l* are the same as those for 0·45 *l* and for 0.4*l* with the origin shifted to the other end of the span. The deflection at any point may be written as $\alpha Wl^3/EI$ where, α is a constant depending on the position of the load and the position of the point for which the deflection is required. In each of the above diagrams α has been plotted instead of δ, against the position of the unit load on the span. It is to noted that by altering the spanscale one such diagram can be used for all spans. Hence when such a set of diagrams is available in the design office the major portion of the work is done once and for all. The remaining portion of the work *i.e.*, of finding the deflection for any train of loading is very simple and quick.

Example :—As an illustration of the use of the method, the British Standard Unit Loading for Railway Bridges for a single line of way for gauges of 4 ft. 8½ ins. and over, has been chosen and the deflections for several spans worked out.

Now suppose the maximum deflection at 0·4 *l* is required; the span being 50 feet, for N units of the above loading when the train is moving from left to right. The deflection locus diagram for 0.4 *l* is taken and on a separate strip of paper the unit load trains are marked out. The unit loads must be marked to the same scale in which the length of the span on the given diagram is represented. In this case as the span is represented by 10 inches on the given diagram, 10 inches represent 50 feet. Hence the positions of the loads must be marked on the separate strip of paper to a scale of 5 feet to an inch.

The strip of paper, with the loadings marked, is then placeed on the span and for one particular position of the loads the values of α under each load is read out from the diagram I. The value of deflection due to any one load W is then α W. The total deflection caused by all the loads on the span is then given by the sum all such α W, and due to N units of such loading is $N \Sigma \alpha W$. This then is the deflection at 0·4L for the tried configuration of the train loadings.

The load train is then shifted a little to one side of the previous position and the new value of total deflection is found out. In this way after a few trials the maximum value of the deflection can be found out for the point 0 4l.

The process described above is similar to that for finding out the maximum bending moment from influence line diagrams. Certain amount of common sense is required to find out the possible position of the loads to give the maximum value of deflection. After a little experience two or three trials are generally sufficient to fix up the final load positions for maximum deflection. A subsidiary graph drawn with deflections obtained against movement of any one particular load shall often be of help in the final fixing of the load position for maximum deflection.

The values of maximum deflections of the points at 0·4l, 0·45l, 0·5l, 0·55l, and 0·6l have been determined for the above train of loading moving from left to right for various spans. As noted before in finding the values at 0·55l and 0·6l the diagrams for 0.45l and 0.4l have been used with the direction of the load train reversed. (See table I).

A diagram is now drawn with the maximum deflections at various points against the span. The maximum of the maximum deflections can be found from this diagram and its location fixed for any span. The result thus obtained is checked by finding the maximum deflection for this point by the method outlined for any one point. These are shown tabulated in the figure 4 for various spans. The maximum of maximum deflection does not necessarily lie at the mid-span. It will be seen from the figure 4 that the deviation of the maximum of the maximum deflection from that of the maximum deflection at

the mid-span is about 0·05 per cent in the worst case. Timoshenko has shown (See Ref. 2) that for a single concentrated load the maximum deviation between these two deflections, both being for the same position of the load on the span can be 2·5 per cent. For a train of loading similar to that dealt with the deviation is of the order found above. This is negligible for all practical purposes and hence we should be justified to take the maximum deflection at the mid-span to be the maximum of the maximum deflections. So in order to find out this value we need use only the deflection locus diagram 3, and thus effect a lot of saving in time. One such operation should not take more than half-an-hour for spans near about 100 feet and for shorter spans it is much less.

The maximum values of deflections at mid-span have been determined for several spans up to 120 feet. The total equivalent concentrated load P at the centre, the total equivalent concentrated distributed load W and the equivalent uniformly distributed load w per foot of span to give the same amount of deflection at the centre have been calculated (See Table II). These are shown plotted in figure 5. The corresponding values for any intermediate span can be obtained directly from these curves. It will be noticed from the above diagram that for small spans up to about 20 feet the curves are very irregular. These portions are therefore shown dotted and should not be used directly for reading out the equivalent load values for intermediate spans. This irregularity in short spans is due to the smaller number of loads that can come on the span at a time. The effect of shifting the load train a little is very perceptible. In such cases the required values should be obtained directly from the deflection locus diagram 3. Comparison of the equivalent distributed loads for maximum deflection as given in Table 2 with those for maximum bending moment as easily obtained from the British Standard Specification will at once reveal the fact that these are different, as has been already remarked in the introduction.

Conclusion :—It has been shown that it is possible to find the deflection (Maximum) at any point of the span with a high degree of accuracy. It has also been shown that the maximun deflections may be taken to be the maximum deflection at the centre of the span with a reasonable degree of accuracy,

error being of the order of 0·05 per cent. A comparison with the equivalent loads for maximum bending moment with that for maximum deflection will be shown that should we calculate maximum deflection from the equivalent bending moment loadings we would obtain a higher figure for the maximum of maximum deflection.

In conclusion the writers wish to acknowledge their indebtedness to Mr. A. Macdonald, lately Principal of the B.E. College for kindly permitting one of us to spend part of his time on this work in lieu of practical training.

Reference I :—On a Method of finding Deflection of Beams by S. R. Sen Gupta :—Indian Physico Mathematical Journal, Vol. VI, No. 2, Sept., 1935.

Reference II :—Applied Elasticity : 1925 by Timoshenko.

TABLE—1

MAXIMUM VALVES OF '$\Sigma\alpha$'

FOR BRITISH STANDARD UNIT LOADING FOR RLY. BRIDGES

Span in feet.	MAXIMUM VALUE OF '$\Sigma\alpha$'				
	At ·4 Span.	At ·45 Span.	At ·5 Span.	At ·55 Span.	At ·6 Span.
5	·02469	·02570	·02604	·02570	·02469
10	·02831	·02927	·02950	·02927	·02831
15	·03888	·04075	·04125	·04075	·03888
20	·05070	·05265	·05340	·05265	·05070
30	·06540	·06790	·06860	·06790	·06540
40	·07778	·08055	·08120	·07990	·07656
50	·09029	·09335	·09465	·09282	·08910
60	·10319	·10686	·10807	·10655	·10238
70	·11639	·12130	·12230	·12078	·11639
80	·12877	·13412	·13603	·13458	·12955
90	·14486	·15053	·15250	·15020	·14438
100	·16110	·16730	·16937	·16750	·16122

TABLE—2

EQUIVALENT LOADS FOR DEFLECTION OF SIMPLY SUPPORTED BEAMS

DUE TO BRITISH STANDARD UNIT LOADING FOR RLY. BRIDGES.

Span in feet.	Maximum value of $\Sigma\alpha$ at Midspan	Equiv. concentrated load 'P' (in tons) at centre.	Equivalent uniformly distributed load.		
			Total load 'W' (in tons.)	Load in Tons per foot run.	'w'=load in lbs. per foot run.
5	·02604	1·2500	2·0000	0·4000	896
10	·02950	1·4160	2·2656	0·2266	507·5
15	·04125	1·9800	3·1680	0·2112	473
20	·05340	2·5632	4·1011	0·2051	459
30	·06860	3·2928	5·2685	0·1756	393
40	·08120	3·8976	6·2362	0·1559	349
50	·09465	4·5432	7·2691	0·1454	325·5
60	·10807	5·1874	8·2998	0·1383	310
70	·12230	5·8704	9·3926	0·1342	300·5
80	·13603	6·5294	10·4471	0·1306	292·52
90	·15250	7·3200	11·7120	0·1301	291·49
100	·16937	8·1298	13·0076	0·1300	291·37
120	·20144	9·6691	15·4706	0·1289	288·78

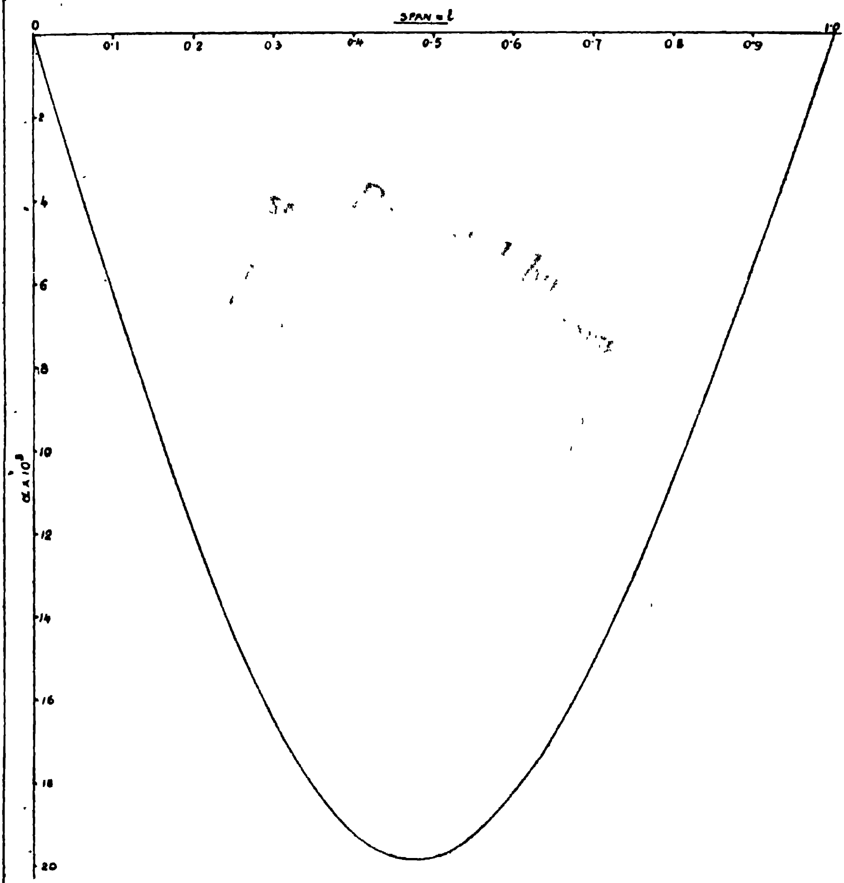
DEFLECTION LOCUS FOR POINT AT 0·4 SPAN OF SIMPLY SUPPORTED BEAMS.

FIG. 1.

DEFLECTION AT 0·4 SPAN $= \alpha \times \frac{Wl^3}{EI}$.

LOAD POSITION	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
$\alpha \times 10^3$	6·3	12·0	16·5	19·2	$19{\cdot}\dot{6}$	$18{\cdot}\dot{7}\dot{3}$	15·0	$10{\cdot}\dot{6}$	$5{\cdot}\dot{5}\dot{3}$

NOTE MAXIMUM VALUE OF $\alpha = 0{\cdot}019975495$ WITH LOAD AT $0{\cdot}47085\,l$.



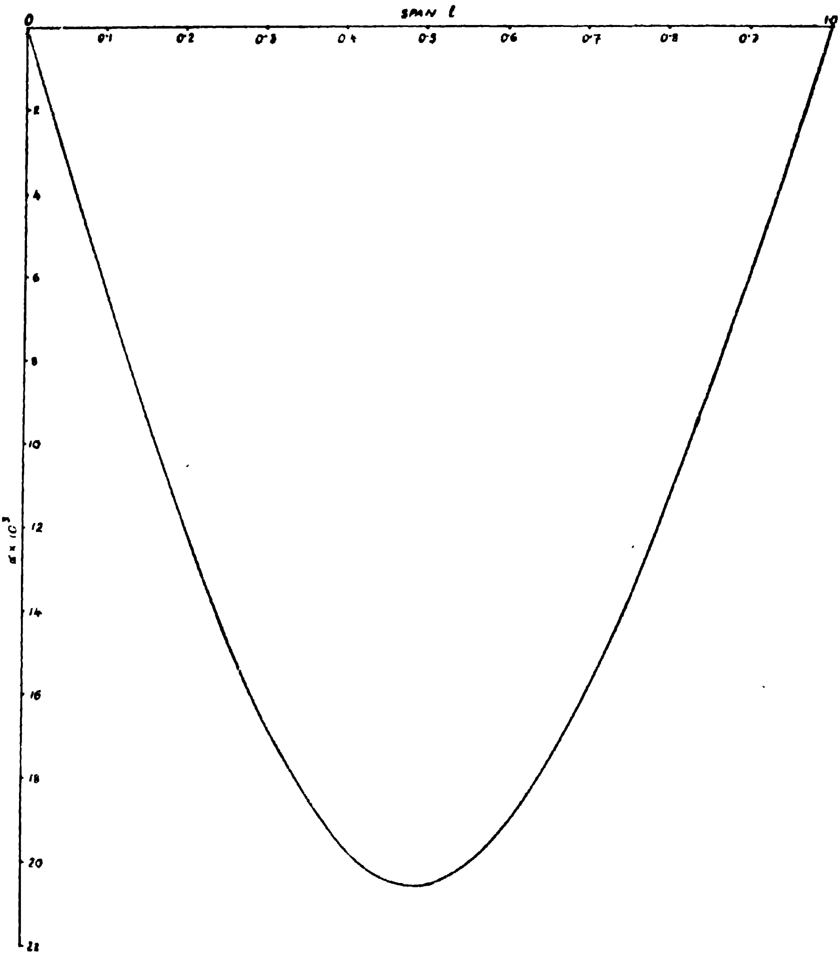
DEFLECTION LOCUS FOR POINT AT 0·45 SPAN OF SIMPLY SUPPORTED BEAMS.

FIG. 2.

DEFLECTION AT 0·45 SPAN $= \alpha \times \frac{Wl^3}{EI}$.

$\alpha \times 10^3$	6302	12054	16706	19708	20418 7	20·5[illegible]	19125	15919	11363	5 906
LOAD POSITION	0·1	0·2	0·3	0·4	0·45	0·5	0·6	0·7	0·8	0·9

NOTE: MAXIMUM VALUE OF α = 0·0205591 WITH LOAD AT 0·4844 l.



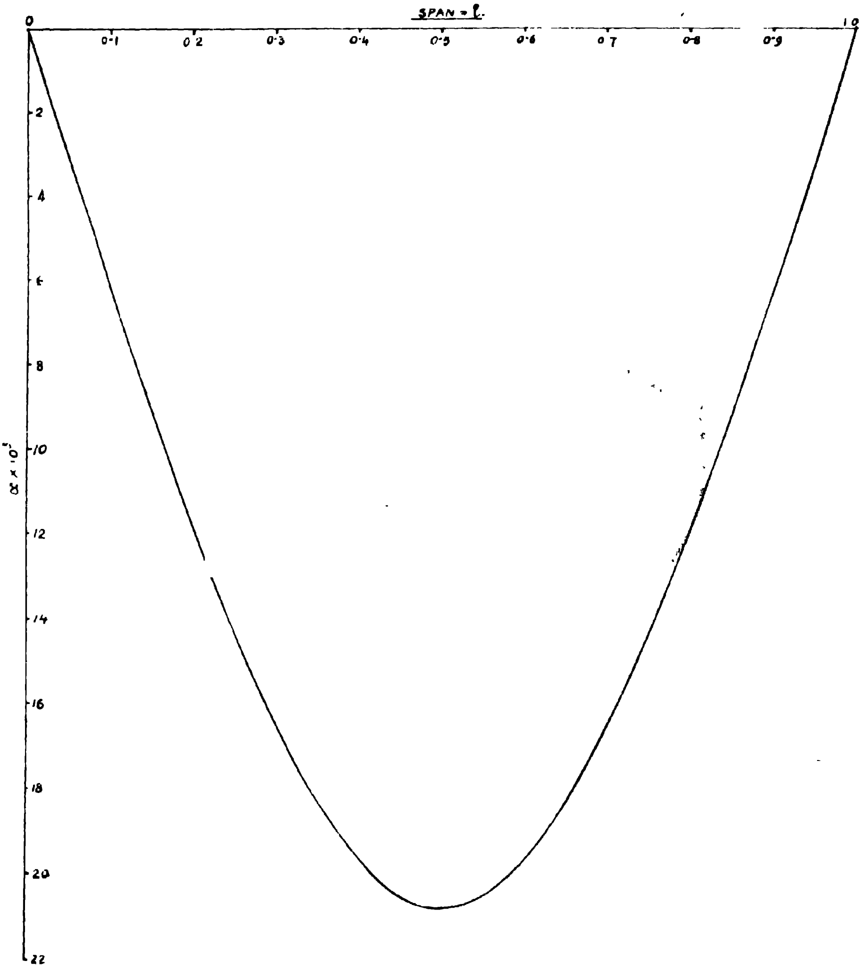
DEFLECTION LOCUS FOR POINT AT 0·5 SPAN OF SIMPLY SUPPORTED BEAMS.

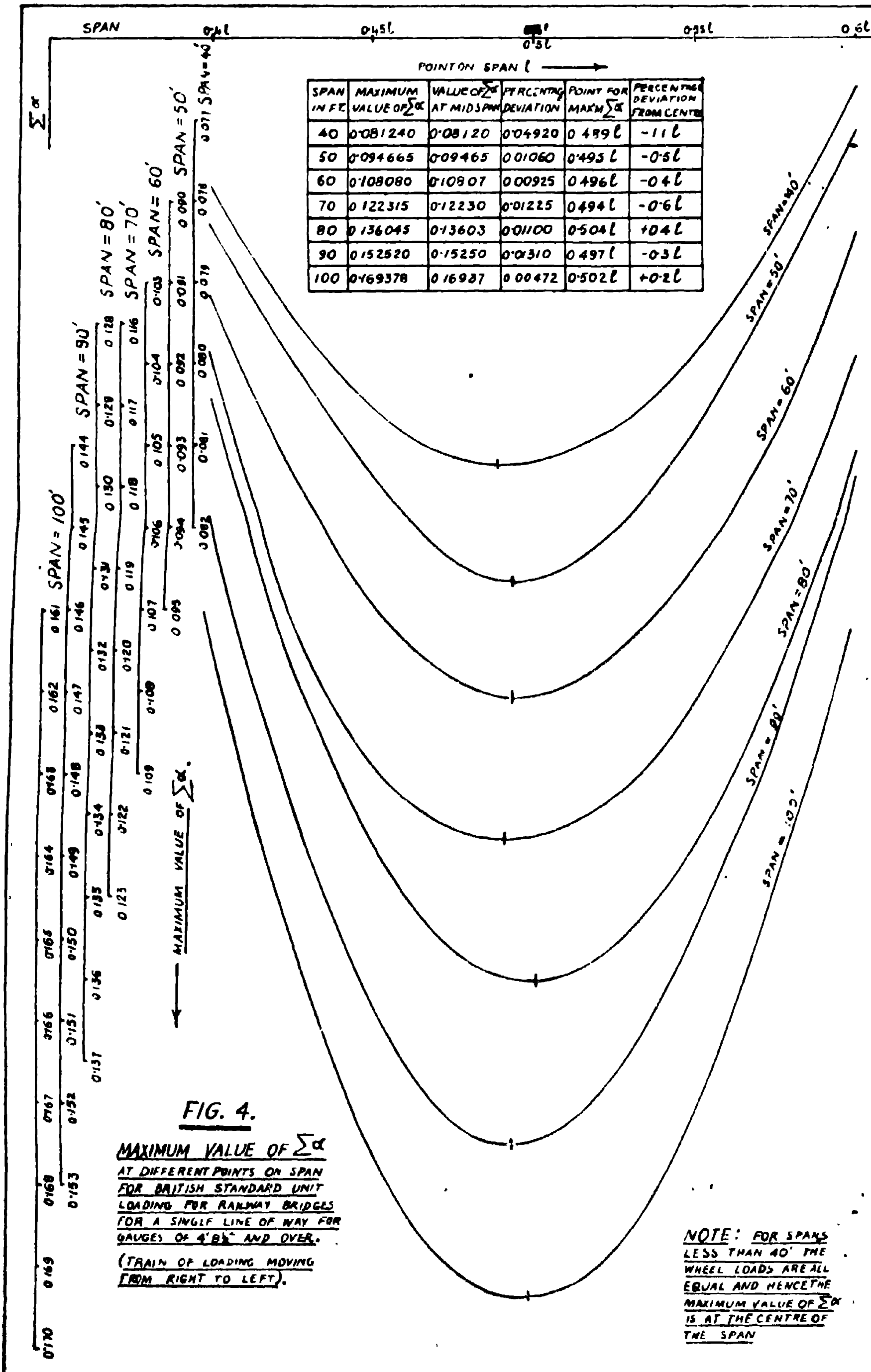
FIG. 3.

DEFLECTION AT 0·5 SPAN = $\alpha \times \frac{Wl^3}{EI}$

LOAD POSITION	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
$\alpha \times 10^3$	6·16	11·83	16·5	19·6	20·83	19·6	16·5	11·83	6·16

NOTE: MAXIMUM VALUE OF α = 0·02083 WITH LOAD AT 0·5 l.





SPAN IN FT.	MAXIMUM VALUE OF $\sum\alpha$	VALUE OF $\sum\alpha$ AT MIDSPAN	PERCENTAGE DEVIATION	POINT FOR MAXM $\sum\alpha$	PERCENTAGE DEVIATION FROM CENTRE
40	0·081240	0·08120	0·04920	0·489 l	-1·1 l
50	0·094665	0·09465	0·01060	0·495 l	-0·5 l
60	0·108080	0·10807	0·00925	0·496 l	-0·4 l
70	0·122315	0·12230	0·01225	0·494 l	-0·6 l
80	0·136045	0·13603	0·01100	0·504 l	+0·4 l
90	0·152520	0·15250	0·00310	0·497 l	-0·3 l
100	0·169378	0·16937	0·00472	0·502 l	+0·2 l

FIG. 4.

MAXIMUM VALUE OF $\sum\alpha$ AT DIFFERENT POINTS ON SPAN FOR BRITISH STANDARD UNIT LOADING FOR RAILWAY BRIDGES FOR A SINGLE LINE OF WAY FOR GAUGES OF 4'8½" AND OVER.

(TRAIN OF LOADING MOVING FROM RIGHT TO LEFT).

NOTE: FOR SPANS LESS THAN 40' THE WHEEL LOADS ARE ALL EQUAL AND HENCE THE MAXIMUM VALUE OF $\sum\alpha$ IS AT THE CENTRE OF THE SPAN

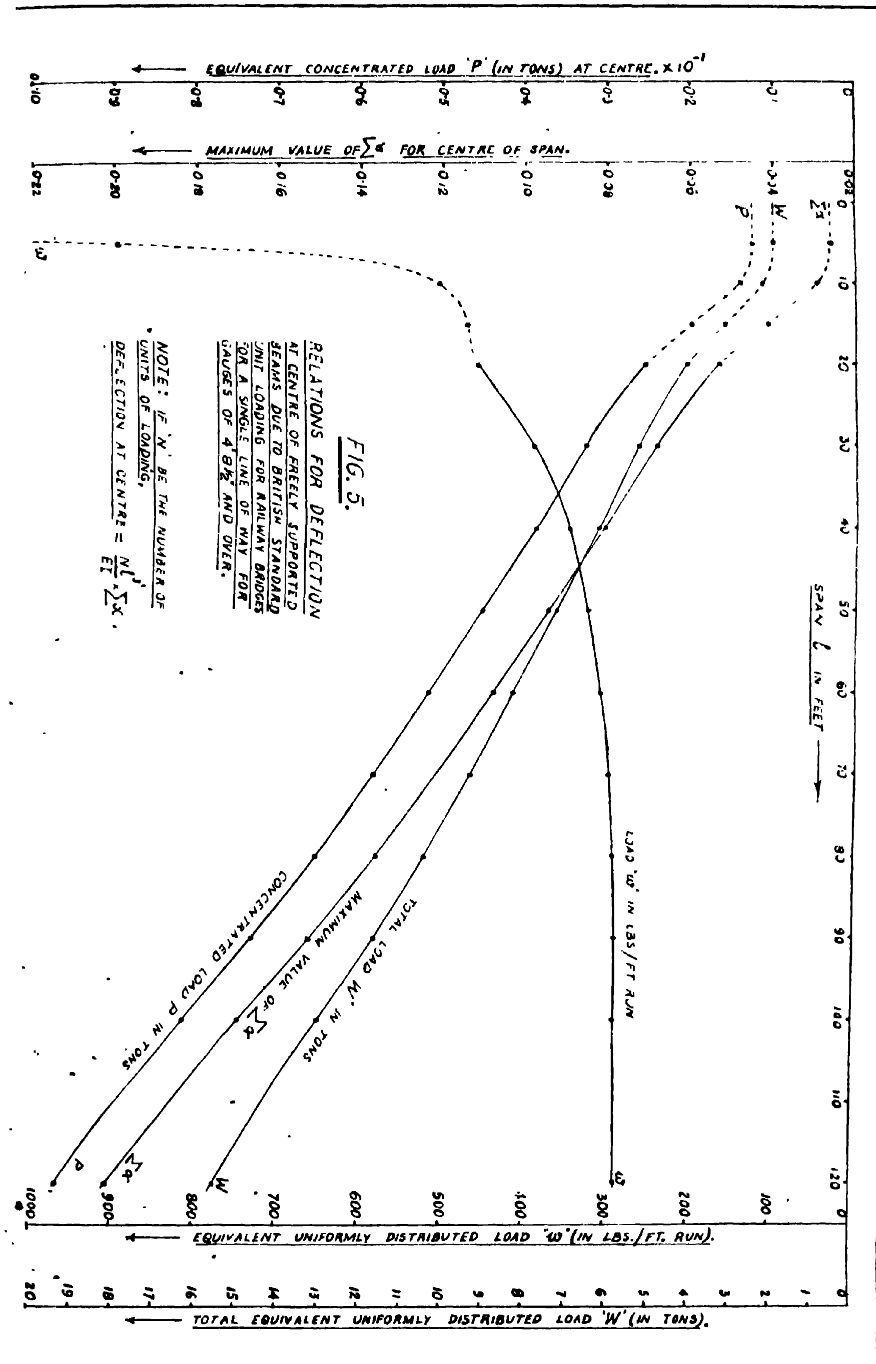


FIG. 5.
RELATIONS FOR DEFLECTION
AT CENTRE OF FREELY SUPPORTED BEAMS DUE TO BRITISH STANDARD UNIT LOADING FOR RAILWAY BRIDGES FOR A SINGLE LINE OF WAY FOR GAUGES OF 4' 8½" AND OVER.
NOTE: IF 'N' BE THE NUMBER OF UNITS OF LOADING,
DEFLECTION AT CENTRE = $\frac{Nl^3}{EI} \cdot \sum x$.
EQUIVALENT CONCENTRATED LOAD 'P' (IN TONS) AT CENTRE. × 10^{-1}
MAXIMUM VALUE OF $\sum \alpha$ FOR CENTRE OF SPAN.
SPAN l IN FEET
EQUIVALENT UNIFORMLY DISTRIBUTED LOAD 'w' (IN LBS./FT. RUN).
TOTAL EQUIVALENT UNIFORMLY DISTRIBUTED LOAD 'W' (IN TONS).
CONCENTRATED LOAD P IN TONS
MAXIMUM VALUE OF $\sum \alpha$
TOTAL LOAD 'W' IN TONS
LOAD 'w' IN LBS/FT RUN

ACTIVITIES OF LOCAL CENTRES.

A General Meeting of the Institution of Engineers (India), Bombay Centre, was held on the Wednesday 14th September 1938 at 6 p.m. (S.T.) in the Conference Room, B. E. S. & T. Offices, Fort, Bombay, when Mr. S. B. Joshi, A.M.I.E., gave a talk on "Engineering Contracts."

Mr. E. A. Nadirshah, Chairman, occupied the Chair.

40 members were present.

Mr. S. B. Joshi. Mr. Joshi in introducing his talk said that under rule 'J' of the Royal Charter granted to our Institution it was stated that the Institution should encourage Equitable Contracts and prepare such documents as would help Engineers in securing equitable contracts. He first examined the part that the Engineers play in giving out engineering contracts. The Engineer generally invited tenders from intending Contractors by a public notification but it was found that no particular principle was followed in deciding upon the form of tender—lump sum tender, percentage tender or item rate tender. The Bombay Municipality and the Military Department restricted percentage tenders and lump sum tenders only to some suitable types of works, but P. W. D. and other private Engineers completely disregarded any principle on which the form of tender was to be based. It was now necessary that our Institution framed some rules in this matter for the guidance of Engineers.

In lump sum tenders, some Architects gave incorrect quantities of work, supplied insufficient data, did not prepare complete drawings, with the result that some uneducated Contractors who happened to give the quotation on the basis of such imperfect data, came to grief in the end. In percentage tenders, quantities under different items were given but generally the Engineers laid down a stipulation that the Contractor should

not be entitled to any compensation if the quantities under different items were increased or decreased. It was a common experience that the estimated quantities under some items ultimately varied to the extent of 100% to 200%.

Coming to the question of earnest money, Mr. Joshi continued that with every tender some amount of earnest money was to be deposited and that there was no uniformity of practice. Under Section 5 of the Indian Contract Act the right to revoke a proposal or an offer was recognized and the irrevocability of tender for Public Works was only an exception as in the famous case—Secretary of State *vs.* Bhaskar Krishnaji—wherein it was decided that "statutory power to make rule for contracts for departmental business will justify the local Government in prescribing among the conditions of tender for Public Works that a tender shall not be withdrawn before acceptance or refusal." But such a privilege was not to be abused by delaying the decisions for a period of nine months or a year. Surely the Contractor should not be denied the right of withdrawing his tender and of getting refund of his earnest money.

It was mentioned in all tender forms that tenders would be opened in the presence of Contractors if they so desired and that they could have inspection of rates quoted by other Contractors. The object of this rule was obvious—no Contractor should have any cause for complaint of malpractice at the hands of either the Engineer or his staff. This practice was strictly followed in the Bombay Municipality, but there were Engineers who felt it below their dignity to open tenders in the presence of Contractors.

It had been said that the present-day Engineer was getting lazier and it was found that he was deficient in taking correct measurements and in properly estimating the job. This was reflected in the tender form prepared by him and the data and the drawings supplied along with the tender form. It might be argued that if there were so many defects in drawings and data, how was it that most of the works were completed without a hitch. The reason was that there were always stringent conditions in the contract which compelled a Contractor to agree to everything which the Engineer ruled. Therefore in the study of local conditions, the first local condition the Contractor studied was to inquire who the Supervising Engineer was likely to be.

With regard to the conditions of the contract it was not generally known that many of the conditions were such as would not stand in a Court of Law—*e.g.* it was mentioned in the contract that Architect or the Engineer-in-Charge could not be made a party to any suit or proceedings with regard to any matter under the contract. Such a condition was void under Section 28 of the Indian Contract Act.

With reference to clauses in contracts referring to Penalties or Forfeiture a lot of misunderstanding existed as regards the exact implications of such clauses. Law would give the actual loss sustained by any one party but would not punish the other party, so that the law generally gave relief against Penalty and Forfeiture in appropriate cases.

Section 74 of the Indian Contract Act laid down that where a penalty was stipulated for a breach of contract, the party complaining was entitled to reasonable compensation subject to maximum amount stipulated. It had also been ruled by Indian High Courts that mere use of the words 'Liquidated damages and not penalty' would not convert what under the circumstances of the case was a penalty into liquidated damages.

It was also found that for the same kind of work the specifications of the P. W. D., Municipality and the private Engineers widely varied. It was high time that the Institution framed some standard specifications for the guidance of Engineers in the cities and in the mofussil.

Coming to the question of disputes and their settlements it was a general principle of law that "No man shall be a judge in his own house." But in engineering contracts, the settlement of disputes was left to the arbitration of the employer's agent, *viz.* the Architect or the Supervising Engineer, as the case may be. This was fundamentally wrong but it was necessary in the nature of circumstances, because if contractors and the employers were required to take recourse to law courts the work would never be completed and there might arise endless litigations in some cases. So as a matter of public policy it was good that Engineers were given such deciding powers. But the question was—did they exercise the power properly? There was a lot of misunderstanding as to the exact status of an Engineer when he was asked to decide a particular point; strangely enough some time he had to adjudicate upon his own

decisions or the decisions of his subordinates. It had been established by judicial precedent that the status of an Engineer during the execution of the work was that of an agent of the employer while his status at the time of exercising his power of adjudicating the disputes was not that of an employer's agent but he exercised such authority in a quasi-judicial capacity.

In conclusion Mr. Joshi said that his aim in pointing out these practices in Engineering Contracts was to have them improved so as to maintain the sanctity of the profession and encourage equitable contracts and to devise some rules by which the practices in different parts of the country were made uniform.

Mr. F. E. Bharucha.

Mr. Bharucha in opening the discussion congratulated the lecturer for giving such an interesting talk and he hoped that Mr. Joshi would come forward with a paper on the subject and submit it to the Institution to be printed in the Journal. He supported the idea for arbitration as suggested by the lecturer and appealed to the Bombay Centre to take up the question.

Messrs. P. P. Adalja, T. R. S. Kynnersley, R. K. Nariman and S. M. Postwala also took part in the discussion.

The Chairman.

The Chairman, Mr. Nadirshah, cleared some of the points referred to by Mr. Joshi regarding the Bombay Municipality and supported Mr. Joshi's suggestion that one sided contracts should as far as possible be avoided. He also agreed with the lecturer that Engineering Institutions should take up this question and prepare at least a general form of contract and distribute it to other bodies.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre, was held on Wednesday, 2nd November 1938 at 6 p.m. (S.T.) in the Conference Room, B. E. S. & T. Offices, Fort, Bombay, when Principal Shiv Narayan, M.I.E. gave a talk on "Electrical Power Development."

Mr. F. E. Bharucha occupied the Chair.

40 members and 20 guests were present.

Principal Shiv Narain.

The speaker at the outset showed a number of slides depicting old and new types of electrical machines and appliances of various kinds. Coming to the subject proper, he referred to

his paper written for the All-India Industrial Conference held at Lahore on 30th December, 1910 when the electrical power was in its infancy in this country. He then took up the questions of generating stations, imports of electrical machinery, manufacture of electrical articles, educational institutions for would-be electrical engineers, new electrical policy advocated by the All-India Electric Conference, measures for industrial advancement suggested by the recent Committees and suggestions by the speaker himself with particular attention to the education and training of electrical engineers and the establishment of Research Bureau for estimation of power required for starting industries in India. Facts and figures were quoted from several books including the speaker's volumes on 'Hydro-Electric Installations of India' and 'Indian Water Power Plants.' The steady growth of electrical power supply in cities of this province was made clear by the statistics and the graphs relating to the B. E. S. & T. Co., Ltd. Reference was also made to schemes in hand and under contemplation, about which the Institution of Engineers (India) should be consulted by the Authorities concerned.

Mr. E. A. Nadirshah.

Mr. Nadirshah in opening the discussion congratulated the Author for his interesting talk and agreed with the suggestions made by the Author with reference to the training of electrical engineers in this country and suggested that the Institution should seriously take up this question.

Messrs. V. R. Blundell and T. R. S. Kynnersley also took part in the discussion.

The President.

The President, Mr. F. E. Bharucha, thanked the Author for coming down to Bombay and giving such an interesting talk. He agreed that Bombay should have a test house where all electrical goods could be tested before they were offered for sale to the public. He also agreed with the remarks made by Mr. Nadirshah and requested the Author to send his suggestions to the Committee of the Bombay Centre so that proper steps could be taken in the matter. He regretted that the industrialists in the country did not come forward to take up apprentices in their services with the result that apprentices and even graduates had to wait for months before they got a suitable job. In conclusion he proposed a vote of thanks to the Author which was carried unanimously.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Wednesday, 14th December 1938 at 5-45 p.m. (S.T.) in the Institution Room when Rao Saheb N. S. Joshi, B.E., A.M.I.E., gave a talk on "Report of the Irrigation Inquiry Committtee of the Government of Bombay."

Mr. T. R. S. Kynnersley, the Chairman, occupied the Chair.

48 members were present.

The subject-matter of the talk was the continuation of his previous one on "The Difficulties in Deccan Irrigation" as given before the members of the Centre on 21st June, 1938. Rao Saheb Joshi first summarized these as falling under three heads :— Rao Saheb N. S. Joshi.

1. That the system of Deccan Irrigation needed costly reservoirs and a long canal to cover a large area under famine conditions.

2. That the people, where lands were commanded, were not willing to make full and guaranteed use of the water thus made available but gambled on rain.

3. That the loss in transit through canal distributaries and outlets was heavy.

There was still another point for consideration before the Committee, *viz.*, the absence of large irrigation schemes in Gujrat and Karnatak.

He then explained how the Committee under the guidance of Sir M. Visweswar Ayyer dealt with each of these problems. He explained that the Government did not feel the necessity of large irrigation schemes in Gujrat because the rainfall there was generally ample and well-spread with the result that they did not fall under famine tracts. On the other hand areas in Nagar, Sholapur, and other eastern districts in the Central Division suffered regularly from the scourge of famine and it was hence that the Government gave their full attention to

these areas by constructing large irrigation schemes. Government also lost large sums as unrecovered revenue and had to speed on protection work in these famine tracts during actual famine. Karnatak and especially Bijapur District and also parts of Dharwar and Belgaum needed protection from famine. The geographical situation of these tracts was, however, such that canal if constructed needed very long length and the percolation losses were so heavy that a canal was impossible. There was once an idea of extending the Nira R. B. canal down to Bijapur but this meant a canal 300 miles long and the idea was given up.

The Irrigation Inquiry Committee, however, suggested that some large projects should be taken up particularly in Karnatak and Government were seriously considering this.

Regarding the cost of Irrigation schemes in Deccan—that was an unavoidable difficulty and had to be faced. The real value of guaranteed water supply for irrigation had not been understood by people who had little or no enterprise on account of their poverty or ignorance. On the other hand Government had followed the policy of giving irrigation in small patches to these local land-owners. If large scale irrigation was practised it should be possible to have large water-rates and the canals would then be able to support themselves. This view had been partly accepted by Government and the Committee had given their full support to the same. The Committee in their report had shown that if all the quantity of water stored in the lakes were utilized, the canals would be able to almost support themselves. The Committee had prescribed that 8·6 acres of mixed crop, equivalent to about 1¾ acres of full term cane, would be irrigated by every million c.ft. of water stored. He feared that to be an optimistic view and was wrong by 30 to 40%. On the other hand the Committee had recommended lower water rate to cultivators. They had also been too lenient with the sugar factories by recommending that part of the cost of drainage in allotted factory areas should be borne by Government. All that meant a monetary loss to Government if the Committee's recommendations were accepted. Actually the speaker considered that rate of water for sugar crop deserved to be increased by about 50%, as sugar companies were business concerns, and

it was not fair that the public at large should bear the burden for the sake of allowing lower water rates to those sugar companies who would make large profits.

The second difficulty regarding people not understanding the value of guaranteed water supply had been solved by the Committee by insisting on long term contracts without exemption or cancellation, as was the case at the time. This was expected to meet the requirements. Actually it was Sir M. Visweswar Ayyer himself who was the father of the "Block System" on Deccan canals and this was meant for creating a continuous demand of water and stopping the gamble on rain. Only instead of allowing blocks to individuals at isolated patches Sir M. Visweswar Ayyer wanted that they should all be in one selected patch in each village and the idea was certainly worth trying, being on the line of *phad* system in Nasik and Khandesh. The solution of the third difficulty also partly lay in the above mentioned recommendations of the Committee. However the losses in the Canal amounted to as much as 33% of the total discharge at the head of the canal, and this difficulty remained unsolved. The only possible solution for that lay in limiting the length of each canal to about 1/3rd of its existing length. It would, however, result in large famine tracts being left unprotected. Ideal condition would be to limit the length of the perennial section to a minimum and to allow only monsoon irrigation in the rest of the area under command. The Committee had not, however, considered that view seriously due to vested interest involved in established irrigation lower down each of the canals.

Rao Saheb Joshi paid a warm tribute to the labours of the Committee for the voluminous amount of information they had to scan in a limited time and congratulated them on their achievements in spite of the obvious faults as noticed by him.

Dewan Bahadur V. G. Shete, and Messrs. R. N. Joshi, S. B. Joshi and R. K. Nariman also took part in the discussion.

In conclusion the President thanked the lecturer for giving an interesting talk and proposed a vote of thanks to him which was carried unanimously. The President.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Monday, 20th February, 1939 at 6 p.m. (S.T.) in the Institution Room when a debate on "Rent Control" was held. Messrs. S. V. Parulekar, C. R. Beale and J. D. Daruvala took part in the debate.

Mr. T. R. S. Kynnersley, the Chairman, occupied the Chair.

34 members and 7 guests were present.

Mr. S. V. Parulekar.

Mr. Parulekar in opening the debate said that 'Rent Control' was not an emergency measure but was the normal requirement of an industrial town like Bombay. Housing conditions in Bombay were horrible. Three-fourths of the population were living in single room tenements with an average of four heads per room. Cases were not wanting where nine families or even hundred persons lived in one room. This state of affairs resulted in high death rate and infant mortality, as could be revealed by the census report of 1934, and from the investigations carried out by the Bombay Municipality. Infant mortality in Bombay was 666 per thousand as against 80 per thousand in London. In one room tenements in Bombay infant mortality was 829 per thousand. People lived in one room tenements because they could not afford to pay for more rooms. They were already paying 14% of their earning towards rent and if they had to live in spacious houses, without reduction of rent, they would be required to pay beyond their earning capacity. It was as much a right of every individual to have a good house to live in as it was his right to have air, light and food. If he could not have it at a reasonable rent, due to monopolized position of the Landlords, the State must intervene.

Mr. C. R. Beale.

Mr. Beale of Messrs. Gilbert-Lodge & Co., Ltd., speaking for the Landlords, in place of Mr. Gordhandas G. Morarji who could not come, said that Mr. Parulekar had made a good case of State Housing but a bad one for 'Rent Control.' Landlord could not be expected to carry the burdens of industry. Tenant standard was measured by what they were prepared to pay. Rent restriction would result in shortage of houses for the poor. That was the result of Rent Restriction Act in

England. General impression that the Landlord got a good return was not correct. He had many out-goings by way of vacancies, repairs, etc. It was the speculator, who sold properties to the Landlords, that was responsible for increase in rents. It was now an accepted principle that providing houses for the poor and industries was the duty of the State and the Municipality. It was so in England, Scandinavia and other countries. Obviously if the Landlord did not get his due return he would invest elsewhere. It was therefore clear that overcrowding and consequent high death rate was the burden of the State and the Industrialists and not of the Landlord. Bad planning of the city was also partially responsible for the creation of slums.

Mr. J. D Daruvala.

Mr. Daruvala said that it was inequitable to tax one particular class of society when that class was not really responsible for the overcrowding and consequent unhealthy conditions. It was wrong to say that the average Landlord was getting more than what he was getting during the time of Rent Act. Statistics showed that the number of vacancies in some of the overcrowded areas of Bombay were daily increasing. Prices of building materials had steadily come down and the rent had also correspondingly come down. Rent was controlled by the normal economic forces of prices of materials and other conditions of the money market. It was suicidal to restrict the natural current of economic forces. After all the Landlord must get his due return on his investment otherwise he would not come to invest in buildings and his investment would be diverted to other channels. Landlord was a sober type of investor and it would not be fair and beneficial to society to scare the Landlord from the building industry. Rent restriction in such a case would defeat its own purpose. It would result in more overcrowding, due to shortage of houses, and the building industry would be paralysed by rent restriction measures. The proper remedy against overcrowding was to encourage the mill workers to live in the suburbs—away from the mills—and to provide cheap transport facilities. Educating the poor classes was also necessary as it was the experience of the Bombay Municipality that the poorer classes convert verandahs into enclosed rooms and sublet them. They have to be taught the disastrous consequences of overcrowding which they could not appreciate.

Messrs. K. D. Bhagwagar, F. E. Bharucha, G. P. Dandekar, S. B. Joshi, F. D. Mehta and R. K. Nariman also took part in the discussion.

The Chairman. The Chairman also stressed the importance of educating the poor workers and complemented the lecturers for the way in which they made the debate interesting and instructive.

The meeting terminated with a vote of thanks to the Chair.

An Ordinary Meeting of the Institution of Engineers (India), Bombay Centre, was held on Friday, 17th March 1939 at 6 p.m. (S. T.) in the Conference Room, B. E. S. & T. Co., Ltd., Bombay when Mr. G. P. Dandekar, B.E., A.M.I.E., gave a talk on "Revision" of Building Bye-Laws and Regulations with a view to bring them up-to-date.

Mr. T. R. S. Kynnersley, the Chairman, occupied the Chair.

40 members and 58 guests were present.

Mr. N. V. Modak made an introductory speech.

Mr. G. P. Dandekar. Mr. Dandekar in introducing the talk said that the work of revision of Building Bye-Laws was undertaken during the last decade in most of the important cities in the world. He then showed, by means of a chart, the population of Bombay from 1861 to 1931 and explained how due to sudden rise in India's export cotton trade during the American Civil War of 1860 the population of about 8 lakhs was housed in a small congested locality (Mandvi areas and near the docks) in the absence of adequate public utility services. These insanitary conditions continued from year to year, until the year 1888 in which a comprehensive Act was passed. It controlled the construction of private buildings, made provisions as regards height and ventilation of rooms, prescribed the width of new public streets and empowered the laying of set-back lines. It also conferred the power to frame Bye-Laws which were for the first time enacted in the year 1892. These Bye-Laws permitted the height of building to $1\frac{1}{2}$ times the width of the abutting street and stipulated an open area for living room to 1/10 the floor area. The Act was further amended in 1905 and contained the famous Sections 349A and 349B controlling the

height of new buildings as well as those for addition over existing buildings. The Bye-Law 353A regarding completion certificate by a Licensed Surveyor was also framed. In 1910 a new set of Bye-Laws was introduced when a 7′ open space for a height of 70′ was demanded as against 20′ demanded under the existing Bye-Laws.

The sanitary conditions continued to be appalling and the City Improvement Trust was established in the year 1898.

Following the footsteps of the Improvement Trust, the Building Bye-Laws were amended in 1919 to adopt the $63\frac{1}{2}^{\circ}$ rule for non-scheduled areas—though the old Bye-Law 41 still applied to scheduled areas.

No satisfactory improvement in the sanitary conditions of the scheduled areas was however noticeable and the Municipality was faced with the problem of overhauling all the Bye-Laws to bring them up-to-date. Experience showed that amending the Bye-Laws from time to time in a haphazard manner did not give the desired results and the revision of Building Bye-Laws must be done on a preconceived plan and a chalked out programme.

City is a living organism and a town planner must have the structural aspect of his building with due regard to the Geological formation of the land and the annual rainfall. He must determine the orientation of the streets consistent with the prevailing direction of the wind and the latitude in which the city was situated.

The lecturer then illustrated, with the help of a chart, the direction of the prevailing winds and the desirable direction of new streets. He also illustrated, by means of an astronomical model, prepared by Mr. Trollip of the B. E. S. & T. Co., Ltd., how the streets in Bombay (situated at 19° latitude) if laid in the above direction would get sunlight throughout the year for a few hours of the day. He also showed how the model illustrated that the heights of the buildings in Bombay should not exceed $1\frac{1}{4}$ times the width of the street.

The Author then illustrated, by means of a chart, the defects in present Bye-Laws and appealed to the Architects of Bombay to look to the Bye-Laws more as Architects than as Lawyers.

Mr. Dandekar then enumerated a few of the most important items controlled by the revised Bye-Laws.

1. Arresting small sub-division of building plots.
2. Compelling the owner to have the development of his own land so as to fit in with the scheme of streets in the locality.
3. Zoning with special rules for each zone.
4. Power to acquire parts of buildings in set-backs.
5. Prescribing regular lines on house gullies to eventually convert them into 10′ passages.
6. Amending Section 337 so as to discourage partial repairs.
7. Amending Sections 349A and 349B to allow greater height than 70′ in specified areas or zones and to regulate the heights on the basis of units of floors of 11′ height.
8. Lighting of passages and staircases.
9. Servants' quarters.
10. Garage accommodation for public buildings.
11. Arrangements for lifting water, fire escapes and lifts for very high buildings.
12. Building lines in addition to set back lines.
13. Visibility at junction streets.
14. Architectural elevation of buildings.
15. Defining front and rear face of the buildings.
16. Front and rear open space within scheduled areas.
17. 5′ minimum space at sides.
18. Giving advantage of a neighbouring open space to an adjoining owner only to the extent of the open space he agrees to leave.
19. $63\frac{1}{2}^\circ$ rule to side open space on which living room abuts.

20. Prescribing minimum floor area of tenements.

21. Licensing of R. C. C. Specialists, Mistries and Contractors.

Mr. Dandekar also mentioned that the drafters of the Building Code had to study the problems of (1) Ribbon Development, (2) Low Rent Housing, (3) Slum Clearance, (4) Over-crowding, (5) Transport, (6) Parking places and Recreation Grounds, (7) Aerodromes, etc.

The Author then emphasized the advisability of preparing a Master Plan for Bombay.

Messrs. P. P. Kapadia, S. B. Joshi, N. V. Modak and a number of guests also took part in the discussion.

The meeting terminated with a vote of thanks to the Chair.

Rural Communications and their Planning formed the subject-matter of a lecture delivered by Mr. G. R. Vartak, A.M.I.E., Engineer, District Local Board, Satara, on 26th May, 1939 at the Bombay Centre.

Mr. Vartak in opening his lecture said that the importance of the necessity of communications facilities between villages was realized only during recent years. Villages in old days were almost self-contained units. Their everyday requirements were all normally supplied in the village itself. Living was simple, vehicular traffic was unknown, and there being no means of communication the population in villages was backward. On account of the depleted economic conditions, villagers were required to move out of their villages in search of employment to supplement their agricultural income, they were also required to rear commercial crops and convey these to the best markets for getting better prices and all these requirements had made them realize the necessity and importance of roads. Coming in contact with modern developments of towns and cities, villagers had begun to feel that they must get all the amenities of life which the city people enjoyed and they were thus dissatisfied with their old and uncomfortable routes of communication.

The existing means of communication in any District showed that the needs of the villages in the area were not even partially met with. Statistics of the seven Districts of the Central Division of Bombay Province showed that the population density per Sq. Mile varied from 105 to 210 and the road mileage per 100 Sq. Miles area varied from 15 to 40 miles and the same per 100,000 population varied from 103 to 270 miles. Comparing the figures for the Bombay Province with those for the United States of America as shown in the report of the Royal Agricultural Commission, the inadequacy of communication facilities was at once vivid.

	Density of population per Sq Mile.	Road mileage per 100 Sq. Miles area.	Road mileage per 100,000 population.
Bombay Presidency (Rural area)	178·6	25·3	140
United States of America	31·5	80	2.550

Scrutinizing the communication facilities in one District, *viz.*, Satara, it was pointed out that out of the total number of 1,300 villages and an equal number of hamlets having a rural population of 10·62 lakhs only about 525 villages having a population of 6 lakhs had some sort of road fairly well maintained within a distance of 2 miles from the village. This meant that nearly 40% of the villages and 56% of the population only had some reasonable road facilities and showed the very urgent necessity of developing roads in rural areas.

The main trunk roads being already in existence, the work of improving subsidiary roads was left to Local Bodies mostly and there being no regular planned scheme considered before undertaking works, the selection of such works was not generally free from local prejudices and likings. Roads serving as link roads and opening communication in isolated parts and useful to a number of villages required consideration in preference to roads serving individual villages, as the former would afford some facilities to areas which were so long undeveloped. Before most of the villages could thus be afforded road facilities within reasonable distances, it would not be a sound policy to

provide roads leading to individual villages as approach roads. A net work plan for a whole District needs being framed in such a way that most of the villages got advantage of someone of the roads proposed in the scheme within a reasonable distance say 1 or 2 miles and that no village having a population of say 1,000 souls or above was cut off from a well-kept-up road.

There must be co-ordination between the different agencies doing work in the matter of public roads and all must have one well-thought-out scheme of development of the area under control. Government alone with the help of technical experts could frame such a development plan and every agency would have then to work towards the final completion of the plan so far as it lay within its sphere of activities. Works carried out without foresight were bound to mean waste as in cases of large sums of money spent on comparatively unimportant roads or negligence in maintenance of roads already improved. Engineers if they devote attention to this important problem of road development of the area where they happened to be working could help immensely towards the advance of the country.

As an illustration of the idea, the existing facilities of road communications in a Taluka and the improved scheme of its development were explained by charts and statements whereby 92% of the population could be served by roads where facilities existed for 56% only.

Villages must have roads joining them with all surrounding villages or hamlets and also leading to the fields but out of such radiating roads, those that were likely to serve the interests of the largest population or were likely to serve as shortest and comfortable routes leading to centres of large business or other activities, must get preferential selection. The remaining roads leading to individual villages or useful for the agricultural operations of a single village might be left to be improved and maintained by the villagers themselves on co-operative efforts.

The lecture was well attended and members took part in the discussions that followed. The subject attracted the special notice of the Bombay Economic and Industrial Survey Committee and Dr. V. K. R. V. Rao, a member and secretary of the Committee specially attended the lecture and got himself acquainted with the details worked out by the lecturer.

Mr. N. V. Modak observed that sites of some of the villages situated in the unhealthy and inconvenient localities would have to be changed in preparing the Master Plan.

The Chairman, Mr. Kynnersley, inquired about the surface of existing roads and their maintenance cost. He observed that cost of cross-drainage works being very considerable would have to be considered in preparing the Master Plan.

The meeting terminated with a vote of thanks to the Chair.

Statement A.

Statement showing areas, towns and villages and their population and length of roads in the 7 Districts of Central Divn.

Division.	Name of district.	Area in sq. miles.	Total population.	No. of towns and cities.	Urban population.	No. of villages.	Rural population	Density of rural population per sq mile.	Existing length of roads. Provincial roads.	Local Board roads.	Total mileage.	Road mileage per 100 sq. miles area.	Road mileage per 100,000 rural population.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Central Division.	Ahmadnagar ..	6,611	9,88,206	7	98,660	1,350	8,89,546	134·5	542	642	1,184	17·9	133	
	East Khandesh ..	4,551	12,06,035	23	2,93,086	1,468	9,12,949	200·6	*681	1,054	1,735	15·9	109·5	
	West Khandesh ..	6,401	7,71,794	8	1,00,408	1,484	6,71,386	104·8						
	Nasik ..	5,882	10,00,048	10	1,56,408	1,636	8,43,640	143·4	515	1,812	2,327	39·5	275·9	
	Poona ..	5,332	11,69,798	12	3,12,700	1,132	8,57,098	160·7	615	900	1,515	28·4	176·9	
	Satara ..	5,053	11,79,712	11	1,12,307	1,330	10,67,405	211·2	500	1,641	2,141	42·3	200·6	
										†604	†1104	†21·8	†103·4	
	Sholapur ..	4,369	8,77,520		2,38,974	708	6,38,546	139·7	360	670	1,030	22·5	161·3	
Total for Central Division ..		38,553	73,72,637	88	14,23,747	9,195	59,48,890	154·3	..	..	9932	25·7	167	
Do. for Northern Division		13,615	40,60,35[illegible]	12	8,89,582	4,817	31,70,770	232·9	..		3125	22·9	98·5	
Do. for Southern Division		25,029	53,97,681	53	7,27,866	7,472	46,69,815	186·6	.	..	6267	25	134·1	
					Average	for	Presidency	178·6	..		.	25·3	140	
	Khatav Taluka of Satara District ..	500	92,538	Nil	Nil	87	92,538	185	40	80	120	24	129·0	
	Do. after communication facilities are developed ..	Do.	Do.	Do.	Do.	Do.	Do.	Do	40	178	218	43·6	235·5	

Remarks :—* Separate figures for East and West Khandesh Districts could not be available.
† Excluding Cart Tracks.

Statement B.

Statement showing number of villages and population in the different Talukas of the Satara District that have got fair facility of communications in having a fairly well-looked-after road within 2 miles.

Name of Taluka or Mahal.	No. of villages in the Taluka or Mahal.	Rural population in Taluka or Mahal.	Number of villages having a fairly well-looked-after road within 2 miles of village.	Percentage of villages in column 4 to total number.	Population of villages having communication facilities within 2 miles.	Percentage of population fairly served by roads to total population.	Remarks.
1	2	3	4	5	6	7	8
1. Wai	111	73,373	47	42·3	44,596	60·7	Partly hilly area.
2. Jaoli	251	66,703	67	26·7	25,983	38·9	Hilly area.
3. Satara	146	95,823	54	37·0	52,342	54·6	Partly hilly area.
4. Koregaon	85	87,176	43	50·5	50,892	58·3	
5. Karad	101	1,28,272	66	65·3	96,546	75·3	
6. Patan	202	1,21,388	59	29·2	55,925	46·0	Hilly area.
7. Walwa	53	1,08,704	32	60·4	73,441	67·5	
8. Shirala	80	57,151	16	20·0	18,612	32·6	Hilly area.
9. Tasgaon	48	87,061	17	35·4	37,326	42·8	Area is scattered and interspersed by several State villages.
10. Khanapur	89	83,577	51	57·3	52,669	63·0	
11. Khatav	87	92,548	48	55·2	66,604	72·0	
12. Man	77	60,586	25	32·5	26,340	43·4	
Total for District	1,330	10,62,362	525	*39·4	6,01,276	*56·6	*Excluding the hilly and scattered area Talukas the averages will be 53·8 for number of villages and 65·3 for population.

Statement C.

Statement showing the formation of village groups into convenient centres and proposal for developing communications in Khatav Taluka of Satara District.

Name of Centre.	No. of villages included in the Centre.	No. of villages having population of 2,000 & above.	No. of villages having population of 1,000 & above but below 2,000.	No. of hamlets under the villages.	Population of the Centre.	Local Fund realized in the area in Rupees.	Area of the Centre in Square Miles.	Existing road length in the Centre in Miles.	Necessary road length for proper development in Miles.	Villages and hamlets that will be benefited by the proposed road length. Being close to road. Villages.	Being close to road. Hamlets.	Being within a mile of road. Villages.	Being within a mile of road. Hamlets.	Being within two miles of road. Villages.	Being within two miles of road. Hamlets.	Villages that will be left beyond two miles of road. Villages.	Villages that will be left beyond two miles of road. Hamlets.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1. Diskal ..	5	2	3	13	10,769	2,756	55·9	2	15	4	4	1	5	..	..	..	4	
2. Pusegaon ..	10	1	6	11	12,301	3,566	56·3	20	27	2	3	7	4	..	2	1	2	
3. Khatav ..	14	1	2	6	11,512	3,784	52·6	5	17	5	..	4	3	3	2	2	1	
4. Waduj ..	9	2	..	10	12,765	4,564	64	24	35	4	2	2	4	..	3	3	1	
5. Pusesaoli ..	7	1	..	5	5,561	1,890	28·9	13	16	3	..	4	2	..	..	..	3	
									10	in	state	area						
6. Vadgaon ..	9	..	2	3	6,232	2,249	34·5	15	21	3	1	4	2	2	..	..	..	
7. Nimsod ..	7	..	5	4	8,201	2,583	51·6	6	18	5	..	..		..	3	2	1	
8. Katarkhatav ..	11	1	1	5	8,660	2,390	49·9	11	19	1	..	5	3	4	1	1	1	
9. Myani ..	10	2	..	6	9,548	2,600	60·3	17	22	2	..	3	3	3	1	2	..	
10. Kaledhon ..	5	2	2	7	6,989	1,481	46·0	7	18	2	1	1	4	1	..	1	2	
Total ..	87	..	..	70	92,538	..	500·0	120	218	31	11	31	32	13	12	*12	15	

$\underbrace{31 \quad 11 \quad 31 \quad 32 \quad 13 \quad 12}$ 75 villages and 55 hamlets will be benefited *i.e.*, 86% of the villages.

* Total population of these 12 villages is 7,233 *i.e.*, 8% of the population. Out of these only 6 have a population of above 500 and 3 villages and 11 hamlets are in the interior of hills.

A General Meeting of the Institution of Engineers (India), Bombay Centre was held on Friday, 21st July, 1939 at 6 p.m. (S.T.) in the Institution Room at the above address when Mr. M. Seshadriengar, B.E. Student, read a paper on "Applications of the Principles of Rigid Frames to Structures."

In the absence of the Chairman, Mr. R. K. Nariman was duly proposed to the Chair.

25 members were present.

Mr. Seshadriengar in introducing his paper said that he wanted to show what were the rigid frames, what were their principles, necessity of their application to structures, how these principles were to be applied to various structures and what were the special advantages that could be derived by recognising that structures ought to be designed on the principles of rigid frames.

Rigid frames were portion of structure consisting of a number of vertical and horizontal or inclined members joined rigidly, such that at the joints the structure resisted fully the bending moments and shears. Use of reinforced concrete and welded steel to most of the structures had brought into being rigid frames. Reinforced concrete by virtue of its monolithic nature made the joints at which members meet rigid. So was the case with welding in steel structures. The principle of the rigid frame was that when one joint of the frame was subjected to a moment, the other joint also got affected thereby affording relief to joint. The frames were indeterminate statically since neither the reactions on the structure nor the stresses in the members could be determined from the condition of the static equilibrium. Statically indeterminate values which were the reactive components at the supports of the frames were determined by use of elastic theory and the bending moment and shears were then computed by ordinary rules of statics.

The Author then explained 19 types of rigid frames. He then proceeded to explain computation of the actual stress in members and providing the requisite sections thereof. He pointed out that rigid frames resisted load essentially by bending of the several members of the frame. Bending stresses, therefore, were to be provided against while the direct stresses were

negligible. He confined himself to two of the most popular methods of treatment of rigid frames. Referring to the General Method he said that it would be applicable to most types of frames irrespective of the conditions of the base or uniformity or otherwise of the sections. By this method indeterminate reactive components were first of all found and the bending moment at the several sections determined afterwards by ordinary principles of statics. The general method was the same as that used in the solution of the two-hinged and fixed arches. The second method was Moment Distribution Method. The value of this method from the practical point of view lay in dealing directly with the moments themselves by simple arithmetic and not depending on small rotation of joints and angular slopes of members. Before proceeding further he defined certain constants used in this method. He explained the fixed end moment as the moment which would exist at the ends of member if its ends were fixed against rotation. He defined stiffness of a member as resistance to rotation for unit rotation at one end when the other end was fixed. He explained the term 'Carry-over-factor' as the ratio of moment at fixed end to the moment producing rotation at the rotating end when one end of the member which was on unyielding supports at both ends was rotated while the other end was held fixed.

He then showed how the value of fixed end moment was easily obtained. The values of the other two constants were obtained by the use of the fundamental equations of members in flexure subject to end restraint :

$$M_A = 2\,EK\,(2\theta_A + \theta_B - 3R) \quad .. \quad (1)$$

$$M_B = 2\,EK\,(2\theta_B + \theta_A - 3R) \quad .. \quad (2)$$

After obtaining the values of the above constants he explained at length the procedure of moment distribution.

The Author then took 19 typical frames mentioned in the beginning of the paper one by one and explained the working of their designs by one or the other of the methods. He had assumed the loading to be vertically down and uniformly distributed.

After enumerating the analysis of rigid frames for several cases the Author enumerated the following practical aspects of the problem :

(1) It is best to make the sections of members simple, say, rectangular.

(2) Where the wall between the vertical members is of R.C. sufficient reinforcement must be used to prevent the separation of the wall from the vertical member.

(3) Before considering the actual design of frame, it will be necessary to make assumptions as to its preliminary dimensions; these are roughly computed using arbitrary co-efficient for moments for dead and live load, varying from $\frac{1}{16}$ to $\frac{1}{12}$ depending upon end conditions.

(4) Sharp corners should never be allowed in rigid frame construction ; at the joints the corners should be rounded up. This rounding up of corners helps to reduce the compressive stress and also removes the necessity of introducing sharp bends in the reinforcement in R.C. frames.

(5) For bending the reinforcement to R.C. frames the moment diagram serves the best guide and the bending of bars must be made as simple as possible.

(6) The joints between horizontal and vertical members must be carefully reinforced. All the reinforcement at the joint should extend from the column into the beam and not from beam to column. Sufficient amount of ties or hoops must be used.

(7) The end conditions of supports of the frame must be properly established, in the construction, in the manner contemplated in the design.

The Author then explained that if the frame was designed for fixed support, the action between the end of support and the foundation must be made sufficiently stiff to resist both the bending moment and the horizontal thrust developed at the end. He recommended slightly heavy foundation to meet the requirements. He also explained how the use of the 'Mesnagar Hinges' serve the conditions of hinged ends for supports.

He further explained that when the rigid frames were designed for R.C. they must be constructed where possible in one continuous operation and that where it would not be possible to do so, construction joints should be used at points of minimum shears.

The Author then enumerated the following advantages of rigid frame principles :—

(1) The greatest advantage derived by the application of the rigid frame principle to structures is the use of minimum sections to members of the structure (without sacrificing strength) which means big savings in cost.

From the designs (applying rigid frames principles) of over half a dozen steel foot-bridges, a couple of R.C. underbridges and some other R.C. constructions which the Author had opportunity to deal with, it was his experience that in general the costs of the structures designed on the above principles work out comparatively much less and vary from 50% to 80% (depending on the type of structure) of the costs of the same structures designed on other considerations.

2. *Ease of construction*—Welding the joint is easier than riveting. Ease of construction in R.C. was well known.

3. Dead weight of structure would be minimum.

4. *Elegance of appearance*—Welded structures look much neater than rivetted ones and present smooth surfaces. This of course goes without saying in the case of R.C.

5. *Ease of maintenance*—It was well known that R.C. structures hardly require any maintenance. In the case of steel structures it is much easier to paint the welded connections rather than rivetted connections of members with their cover plates, packs etc., and thus it was easier to maintain structures with joints welded than with rivetted joints.

The Chairman in conclusion thanked the Author for his interesting paper and regretted that it could not be discussed at length for lack of time. A vote of thanks to the Author was carried unanimously.

The meeting terminated with a vote of thanks to the Chair.

MODERN TENDENCIES IN DESIGN AND CONSTRUCTION OF TRACK

by

A. Vasudevan, B.E., Member.

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PREFACE.

The author has been particularly fortunate in that he had opportunities during the last ten years to study closely the trend in the design and construction of modern track. In this paper he has attempted to bring together in one place all the information available regarding the design and construction of modern track and to review it in the light of experience gained in other countries of the world. The lines along which track design and construction on Indian railways should progress in order that the tracks may be fit to take up the increased speeds and loads coming on them have been generally indicated.

The information regarding Indian railway standard designs and practices has been extracted from the standard drawings and publications issued by the Central Standards Office for Railways. The author's thanks are due to Mr. J. M. D. Wrench, C.I.E., Chief Controller of Standardization, Central Standards Office for Railways for the kind permission accorded to the writer to contribute this paper.

Simla, THE AUTHOR.
August, 1937.

INTRODUCTION.

The progress achieved during the past decade in the methods of design and construction of permanent way has greatly surpassed the achievements of the first quarter of the present century. Two main causes have been responsible for this unprecedented progress. The first and foremost is the loss of the monopoly long held by the railways in the field of transportation. The second is the quinquennium of economic depression that has caused a considerable diminution in traffic handled by railways all the world over.

Railway administrators had in combating the above, to increase the weight and capacity of their rolling stock, and the number and speed of their trains both passenger and goods. Axle loads have had to be more than doubled in consequence. The increase in the speed of trains, introduced in the first instance for relatively light units such as rail cars, to combat road traffic, has subsequently been adopted even for larger units. Thus there are to-day fast passenger trains that run well over a hundred miles to the hour, hauled by monster locomotives both steam and electric.

Notwithstanding the increase in the weights and speeds of vehicles both of which have a pronounced deleterious effect on the track and its maintenance, maintenance engineers have been expected to bring down their maintenance costs, so that modernising permanent way has become primarily an economic problem.

In meeting the above demands, the trend of design and construction of modern track has progressed on the following lines :—

1. Stronger track to take up
    (a) heavier loads, and
    (b) greater speeds.
2. Reduction in maintenance costs.

3. Reducing periods of obstruction to traffic during renewal and replacement.

4. Obtaining more life and service from the materials used.

5. Provision of a smooth running track, liable to cause less damage to rolling stock.

The subject is most conveniently dealt with in the following order :—

Design and construction of modern track to meet modern transportation requirements.

Modernising *existing* track to meet modern transportation requirements.

Financial aspects of modern track.

CHAPTER I.

DESIGN AND CONSTRUCTION OF MODERN TRACK.

Present day loads and speeds.

The axle loads of present day vehicles as used in ten representative countries of the world are as follows :—

Maximum locomotive axle loads.

India ..	21·85 tons. G. I. P.
England ..	20·83 to 22·86 tons.
United States ..	26·58 to *35·66 tons. *(Reading Railway Co.)
France ..	22 tons.
Continent :	
Steam Locos ..	17 to 22 tons.
Electric Locos ..	16·2 to 20 tons.
Turkey ..	17·7 tons.
Canada ..	27·22 tons.
China ..	21·85 tons.
New Zealand ..	23·12 tons.

Future standard for Indian Railways is 22·5 tons—M. L. (Main Line) Engine.

Except in the United States and Canada, axle loads of locomotives on railways are thus well within 25 tons and it appears very unlikely that they will be further increased within the next 10 or 15 years except in countries where the loads are at present under 22 tons.

In 1926, the Railway Board fixed 28 tons as the standard to which the axle loads of locomotives running on H. M. (Heavy Mineral) sections should be designed, but they have since decided that for meeting the traffic demands of the next 15 years, M. L. (Main Line) engines with 22½ ton axle loads

would be more than sufficient. They have consequently abandoned or postponed their programme of renewing or re-conditioning the girders of their main line bridges under 80 feet, to H. M. standard.

Axle loads of passenger vehicles.

The following data will be found to be of interest :—

India	..	16·26 tons.
England	..	9·15 to 14·23 tons.
United States	..	13·15—*23·74 tons. *(Northern Pacific Railway.)
France	..	22 tons.
Continent	..	13 to 19·06 tons.
Turkey	..	8 tons.
Canada	..	18·14 tons.
China	..	15·50 tons.
New Zealand	..	23·12 tons.

It appears unlikely that there will be any further increase in the near future in the axle loads of passenger vehicles either.

Wagon axle loads.

India	..	22·86 tons. E. I. Ry. 22·73 tons. E. B. Ry
England	..	25·76 tons. G. W. Ry.
United States	..	27·32 tons. Pennsylvania Railroad
France	..	22 tons.
Continent	..	15 to 22 tons.
Canada	..	27·22 tons. Canadian Pacific Rly.
China	..	15·5 tons.
New Zealand	..	9·65 tons.

(Indian Railway standard maximum wagon axle load is 19 tons.)

In the matter of wagon axle loads some railways are trying to lengthen their open trucks specially those for carrying rails, so as to carry longer rails, *i.e.*, rails up to at least 60 feet in length.

Maximum weight of locomotives.

There are striking differences in the maximum weights of locomotives as found on different railways of the world.

India	..	201·59 tons. E. I. Ry.
England	..	158·00 tons.
United States	..	444·98 tons. (Chesapeak & Ohio Rly.)
France. Without tender		122·55 tons.
Continent. Without tender		100·2 to 141 tons.
Canada	..	334·62 tons.
China	..	289·67 tons.
New Zealand	..	230·65 tons.

(Indian Railway standard. M. L. Engine 197 tons.)

As there is little likelihood of an increase in the axle loads of locomotives, the maximum weights of locomotives are not likely to be exceeded in the near future.

Horse power of locomotives.

The horse power of present day locomotives ranges from 300 to 3,000, and their hauling capacity varies from 500 to 2,000 tons depending on the speed and the gradient of the section on which they are worked.

Two of the world's largest Diesel Electric Locomotives that have been constructed in Germany, each of which has a brake horse power of 6,000, and a hauling capacity of 17 passenger bogie vehicles at a speed of 110 miles an hour on a section with a ruling gradient of 1 in 500.

Present day speeds.

Present day speeds range from 40 to 110 miles an hour for passenger trains and 15 to 60 miles an hour for goods trains. The general tendency is for a rapid increase in the speeds of

trains both passenger and goods. On Indian Railways, the maximum speed for which the track equipment on main lines has to be fitted is 70 miles per hour.

Track stresses.

A recommendation of the International Railway Congress Association meeting, held in Cairo in 1933 was, that investigations of track stresses should be undertaken in order that the safety of track at high speeds may be properly appraised, and studies are being made by several railways on the effects of these increased loads and speeds on the various track components such as rails, sleepers, ballast and formation.

Prior to 1922 stresses in rails and sleepers were calculated on the assumption that the rail was a continuous beam resting on rigid supports. In 1922 a committee on "stresses in track" set up under the joint auspices of the American Society of Civil Engineers and the American Railway Engineering Association outlined the comparatively recent "elastic theory" of computing track stresses, which now forms the basis of all computations made in connection with the experiments on track stresses that are being carried out.

The elastic theory assumes that the rail is supported continuously on an elastic instead of rigid supports and that this support has a constant modulus of stiffness, *i.e.*, the depression of the track and the upward pressures on the rail are directly proportional to each other. It is further assumed that track conditions are such that negative pressures may be developed under the same conditions of elasticity as positive pressures.

If P is the weight of a load coming on the rail

E the modulus of elasticity of steel

I the moment of inertia of the section of the rail

Y the depression of the rail at any point at a distance x from the wheel load P

Yo the depression under the wheel load P (*i.e.*, when x=o)

p the upward pressure against any point of the rail at a distance of x from the wheel load

po the upward pressure against the point of the wheel load (x=o)

U elastic constant (termed Track Modulus) which denotes weight (usually expressed in lbs.) per unit length of each rail, (usually one inch) necessary to depress the track (rail, sleeper, ballast and road bed) by one unit, (one inch).

(The value of U differs according to the weight of the rail, spacing and size of sleepers and the hardness of the road bed. On some of the 1st class American railways this 'U' has a value as high as 1,600. The track modulus of the best Indian track is as much as 1,300, but ordinary main line track in India cannot be assumed to have a track modulus much in excess of a 1,000).

M the bending moment of the rail at any point

Mo the bending moment of the rail at the point of the wheel load (for a single wheel load) (x=o)

X_1 the distance of the wheel load to the point of the zero bending moment in the rail

X_2 the distance from the wheel load to the point of zero upward pressure

e base of natural logarithms = 2·7183.

Fundamental equations.

The fundamental equations for ascertaining the stresses in the track are as follows :—

$$Y = -\frac{P}{\sqrt[4]{64EIu^3}} e^{-x\sqrt[4]{\frac{U}{4EI}}}\left(\cos x\sqrt[4]{\frac{U}{4EI}} + \sin x\sqrt[4]{\frac{U}{4EI}}\right)$$

and

$$M = \Sigma I \frac{d^2u}{dx^2}$$

$$= P\sqrt[4]{\frac{EI}{64\,U}}\, e^{-x\sqrt[4]{\frac{U}{4EI}}}\left(\cos x\sqrt[4]{\frac{U}{4EI}} - \sin x\sqrt[4]{\frac{U}{4EI}}\right)$$

$$p = -UY$$

x_1 where $M = O$

$$= \frac{\pi}{4} \sqrt[4]{\frac{4\Sigma I}{U}}$$

$$Mo = P \sqrt[4]{\frac{\Sigma I}{64U}} = 0{\cdot}318\ Px_1$$

$$Yo = \frac{P}{\sqrt[4]{64\ \Sigma\ IU^3}}$$

po the maximum intensity of upward pressure $= - U\ Y_0$

$$= P \sqrt[4]{\frac{64\ \Sigma\ I}{U}}$$

x_2 where $p = o$

$$= \frac{3\ \pi}{4} \sqrt[4]{\frac{4\ E\ I}{U}} = 3x_1$$

The combined effect of several wheel loads upon track depression and pressure and the bending moment in the rail, as might occur with a given locomotive or a group of wheel loads may be computed by super-imposition of the effects due to each wheel load computed separately.

The effect which each wheel load has on a rail at different distances from the point of application is graphically represented by the master *diagram for ease of computation. From this diagram, the bending moment developed in the rail as well as the depression at any point in the rail can be read off. The pressure against the rail if required can be calculated by reading off the depression and multiplying it with **U**.

Stresses in Rails.

Actual stresses set up in a rail by vehicles in motion are due to:—

(a) Static wheel loads.

(b) Hammer blow of unbalanced wheel drivers.

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* Fig. (Dl-b) Ry. Board's Technical paper No. 245.

(c) Hammer blow due to steam effect and obliquity of connecting rod.

(d) Speed effect.

(e) Lurching and swaying of a locomotive.

(f) Lateral forces.

(g) Centrifugal forces and excess or want of cant in the case of curved track.

From the formulae detailed in the para above or from the Master Diagram the bending moment caused by a wheel load or a system of wheel loads can be computed and therefrom the stress can be calculated, by dividing the bending moment by the section modulus of the rail. This, however, will only be the stress induced in the rail due to static wheel loads. To this stress must be added the extra stress induced by the wheel loads traversing at speed. In addition, in the case of locomotive driving wheels the stress due to the hammer blow of (a) out of balance of the rotating parts and (b) steam effect and eccentricity of connecting rod, should be further added.

Speed effect.

Rail stress increases with the speed of the traversing load. Professor Zimmermann's theoretical solution of the increase in stress due to a load traversing a track at a uniform velocity, when applied to the railway track, has shown that the increase in stress due to the speed effect, solely on a theoretical basis, is less than 5 per cent of the total stress due to static loads.

Experiments conducted by Professor Dr. Ing. Alexander Wasintynski on the Polish railways, under instructions from the Polish Ministry of Transport, have shown that the increase due to the dynamic effect of wheel loads ranges from 7 to 14% of the stress due to static wheel loads. The increase in stress is more pronounced for speeds ranging from 50 to 70 miles an hour. This increase of stress as is observed by Professor Wasintynski includes in addition to speed effect, increase of stress due to lurching and swaying of locomotives as well as that due to the forward motion of the track flexural wave but not the stresses due to lateral forces. Experiments that have been conducted in India by Mr. Gelson of the Central

Standards Office, to ascertain the increase in stress in rails due to speed effects, have given very interesting results which will be reported shortly.

Lateral stresses.

On a straight track the stresses on the outer flange of a rail base are larger than that in the inner flange, a fact which shows that the wheel pressure has a horizontal component in addition to the vertical component that pushes the rail to the outside of the gauge. This extra stress in the outer flange is 10 to 20 per cent greater than the average stress in the rail flange.

Additional stress in a rail on a curved track.

When trains run over a curved track at speeds lower than that for which the track is canted, there is an extra load on the inner rail of the track. Again when a train traverses a curved path, there is a lateral bending stress on the outer rail due to centrifugal force. The ratio of the lateral bending stress to the vertical bending stress varies according to the design of the locomotives, *i.e.*, according to the total wheel base, distribution of wheel loads, distances between drivers, rigidity of frame, amount of curvature and superelevation of the track and the running speed. This ratio varies from 40—80 per cent for steam locomotives and 30—70 per cent for electric locomotives. For ordinary wagon wheel loads it varies from 20—30 per cent. Generally speaking the maximum lateral bending stress occurs under that driver of a locomotive which produces the maximum vertical bending stress. Thus when considering rail stresses in a curved track it shall have to be noted that the flexural stresses in the rails are much greater than in a straight track.

Stresses in sleepers.

If P is the pressure exerted by the ballast upon a unit surface area of the sleeper, and y its corresponding depression as shown in the figure I below

then $p = cy$

where c is the ballast coefficient.

The value of c varies from 5 kgr/cm^3 to 13 kgr/cm^3 depending on whether the road bed is soft or hard.

If **b** is the width of the sleeper I′ its moment of inertia and E its modulus of elasticity

Then $\Sigma\, I' \dfrac{d^4 y}{dx^4} = -\,b\,p = -\,b\,c\,y.$

or $\dfrac{d^4 y}{dx^4} + 4\,K^4\,y = o$

$$\text{where } K = \sqrt[4]{\frac{c.\,b.}{4\,E\,I}}$$

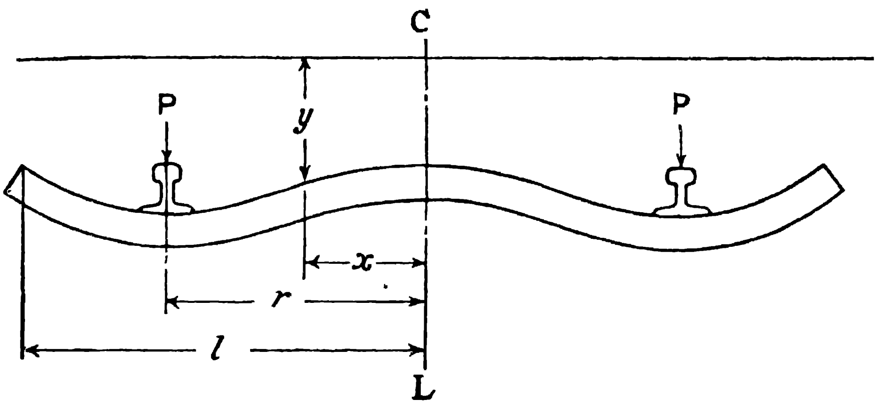


FIG. I.

Solving the above equation

$$y = \left(A_1\, e^{\varphi} + A_2\, e^{\varphi}\right) \cos \varphi$$
$$+ \left(B_1\, e^{\varphi} + B_2\, e^{\varphi}\right) \sin \varphi$$

where $\varphi = Kx$

and A_1, A_2, B_1, and B_2 are constants

which are determined by boundary conditions.

Now

$$M = -\,E\,I' \frac{d^2 y}{d x^2}$$

and $Q = -\,E\,I' \dfrac{d^2 y}{d x^3}$

where M is the bending moment and Q the shear at any section of the sleeper.

In the case of an ordinary sleeper the maximum value of p, M and Q occur in the section directly under the rail.

If these maximum values are represented pr, Mr and Qr

Then

$$Pr = \frac{PK}{b} (n P)$$

$$Mr = \frac{P}{2K} (\mu P)$$

$$Qr = \frac{P}{2} (\mu' P)$$

where (μP), ($\mu' P$) and ($n P$) are the functions of c, K, the length of the sleeper and the gauge of the track.

In the case of the wooden sleepers, it is in addition, essential to see that the bearing area of the rail, on the sleeper is sufficient to ensure protection from failure at the rail seat by abrasion or pressure.

Pressure on ballast.

The pressure on ballast

$$= \frac{KP}{\sqrt{\pi e}} - K^{2x^2}$$

Where x is the horizontal distance between the line of pressure and the point where the pressure is calculated and K is a function of h (the vertical distance between the surface and the point under consideration) and is determined by experiment.

Experimental measurements taken with sleepers 8" in width have shown that the value of p_1 may be calculated by the following empirical formulae:—

$$p = \frac{16{\cdot}8\ pa}{h^{1\cdot25}} (10) - 6{\cdot}05 \frac{x^2}{h^{2\cdot5}}$$

where Pa is the mean intensity of pressure per unit area under the sleeper and h and x are measured in inches.

Pressure intensity directly under the sleeper

$$= \frac{16 \cdot 8 \; p\, a}{h^{1 \cdot 25}}.$$

Stresses in fish plates.

Under vertical loads, fish plates act as simple beams supported at both ends on rail bases and loaded at the middle points by loads from rail ends. The point of action of these three forces depends on the condition of the contact surfaces between rails and fish plates but ordinarily it may be assumed that the pressure from the rail ends acts within 1 inch from the centre of the fish plate and that the pressure from the bottom acts within 7″ to 8″ from the centre. See fig. II.

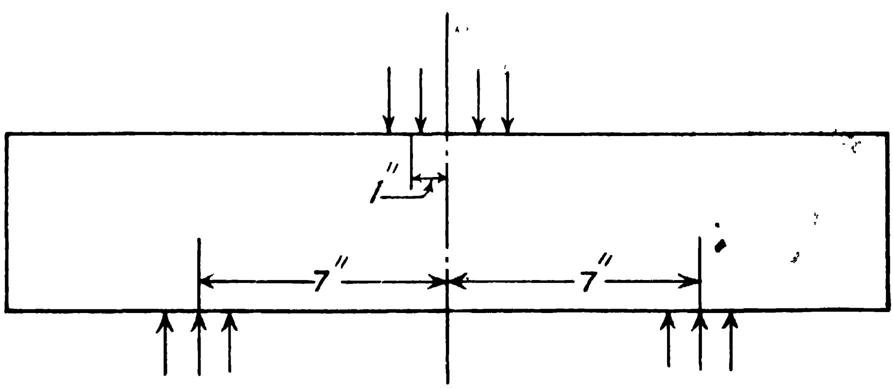


FIG: II

The maximum bending moment occurs in the middle of the section and does not ordinarily exceed 85% of the bending moment occurring in the rail section which it connects.

When the maximum bending moment in a fish plate is small, it indicates that the sleepers nearest the joint are supporting the wheel load at the joint, a feature which is not at all desirable as it produces battered rails. Tightening up of fish bolts increases the bending moment in the fish plates and avoids battering action at the rail ends.

Experiments on track stresses have shown that in most cases, the fish plates used are heavily stressed and are therefore not up to the loads run on the track. It is as such essential in designing new fish plates to see that the two fish plates together are capable of withstanding at least 80—90 per cent of the stresses which the rail connected by them has to withstand.

Permissible stresses in track materials.

The following stresses are permissible—

Rails 14 tons per sq. inch for unworn sections with 32-40 ton steel.

18 tons per sq. inch for unworn sections with 40-45 ton steel.

Bending stress for wooden sleepers 1,400—1,700 lbs. per sq. inch.

Bearing on sleepers 300—350 lbs. per sq. inch.

Road bed pressure 32—40 lbs. per sq. inch.

The operating speed should be so restricted that the sum of the static stresses and the dynamic impact stresses are not in excess of the permissible stresses as stated above.

CHAPTER II

General considerations of track design.

The design of the track shall be such as to suit the traffic that is to run on it, and that the various parts thereof shall be strong enough to withstand the stresses brought into play.

In basing the choice of track components and fittings on their assumed extra lives or extra savings to be had in maintenance costs, consideration shall be given to the financial implications of such a choice as discussed in Chapter VIII of this paper.

Before the final choice of the various track components and the general design of the track is made, due consideration should be given not only to the loads and speeds of vehicles that are to traverse it, but also to factors such as, rains, floods, snow, dust storms and other factors affecting the track, the supervision and maintenance that can be bestowed, the capacity and availability of the labour for maintenance purposes and the nature of the soil of the formation.

In dealing with the details of design of track components, the following order of procedure has been followed. Rails and rail joints have been dealt with first as they form by far the most important track components and account for more than 30—40 per cent of the total cost of the track. Sleepers and their fittings are considered next after which, formation, layout, ballast, turnouts and other minor track components such as check rails, etc., are considered.

Rails.

As has already been stated, increased axle loads and speeds have subjected rails to increased static loads to which must be added dynamical effects which increase rapidly with increased speeds. The metal in the rails, from the moment they are laid in the track, is in consequence subjected to a continuous series of severe strain. To improve the quality of the rails used in

order to reduce the number of fractures and other damages occurring in service and to improve their resistance to wear is the main problem that has been engaging the attention of investigators.

Weight of rail.

The weight of rails laid in the track for high speed operation varies from 90 lbs. to the yard to 152 lbs. to the yard according to the axle loads and speeds which are to operate on it.

The weight of the rails used on the main lines of the railways in the various parts of the world are as follows:—

	weight in lbs. per yard.
India	90 lbs. N.W.Ry.
,, ...	100 lbs. G. I. P. Ry.
,, ...	115 lbs. E. I. Ry.
England	95—100 lbs.
U. S. A.	100—152 lbs.
,,	152 lbs. Pennsylvania Railroad.
France	110 lbs.
Continent	85—100 lbs.
Turkey	80 lbs.
Canada	130 lbs.
China	86·6 lbs.
Japan	100·8 lbs.
New Zealand	100 lbs.
Indian Railway standard ..	B.G. 75, 90 and 115 lbs. M.G. 50, 60 and 75 lbs.

The railways in the United States of America, where locomotives with very heavy axle loads are operated, use rails very much heavier than those used in other countries. The 152 lbs. rail section adopted by the Pennsylvania Railroad is the heaviest adopted on any railway in the world. In Great Britain, including the dominions and the colonies, 100 is the maximum poundage of rail used on main line track except for Canada which uses 130 lbs. rail. The strength of a track increases rapidly as

the weight of the rail increases. The increase in the number of sleepers diminishes the stresses in the rail but this reduction is slight as compared with the increase effected by the increase in the weight of the rail. A track laid with 60 lbs. rail and 2,500 sleepers to the mile has, for example, only the same strength as a track laid with 75 lbs. rail and only 1,500 sleepers to the mile.

The ratio $\dfrac{\text{weight of rail in lbs. per yard}}{\text{maximum axle load of the locomotive in tons}}$ varies from 4·5 to 3·5, the larger figure being for the locomotives with smaller axle loads. The mean value of this ratio is 4·2. This ratio is no doubt very empirical but is useful as a guide in preparing estimates.

In determining the weight of rail to be adopted for main line tracks the following factors should be taken into account.

1. Strength of the rail section *i.e.* the moment of inertia and modulus of section of the type chosen.
2. Maximum axle load of the heaviest locomotive running on the section.
3. Maximum isolated axle load of vehicles running on the section.
4. Track modulus.
5. Sleeper spacing, especially at the rail ends.
6. Maximum speed contemplated with the heaviest locomotive on the section.
7. Riding conditions.
8. Maintenance costs.

The weight of rails usually adopted by the various railways is greater than that calculated theoretically by formulae dealt with under track stresses. In order to meet the requirements listed above most railways are replacing old but serviceable rails with new rails of a heavier section; a few railways are however increasing the number of sleepers without renewing the rail. The wisdom of the replacement with heavier rails has been amply rewarded by the reduction in the number of breakages in all such sections where replacements have taken place.

The standards adopted for Indian railways take into account all the aforementioned considerations and are thus the best for the prevailing conditions.

Type of rails.

The two types of rails most largely in use on the main lines of all railways are the flat footed (vignoles) and the bull headed rails. About 90 per cent of railway track in the world has been laid with flat footed rails, which weight per weight have greater strength and moment of inertia than the bull headed rails.

In England, the Dominions, India and the Colonies, the British standard sections are used for both the flat footed and bull headed rails. In America and Canada the sections approved by the American Railway Engineering Association are used.

Lengths of rails.

The lengths of non-welded rails that are used are as follows :—

India ..	30′, 36′, 39′ & 42′
England ..	45′, 60′, 90′ commonly 60′ L.N.E.R.—120′ (recently rolled)
U. S. A. ..	39′
France ..	24 metres.
Continents ..	15 to 30 metres.
Turkey ..	18 metres.
Canada ..	39′
China ..	32′ 9″—39′ 4½″
New Zealand ..	42′
Indian Railway standard	B.G. 42′ M.G. 39′

Except in England, where the majority of the railways have adopted 60′ as their standard, and the L. N. E. R. have standardized 90′, the lengths of unwelded rails used elsewhere is

well within 45′. The world tendency however is to increase the length of the rail so that the number of rail joints may be reduced.

The rail joint is the weakest link in the track and the advantages to be had in a reduction in the number of rail joints, which are many, are examined in detail when dealing with the question of the welding of rails. Railway Engineers have consequently been always anxious to increase the lengths of rails as a means of reducing the number of joints in the track. Three factors have however conspired against any large increase in the lengths of rails.

1. The capacity of the rolling mills producing rails.
2. Limitations of the means of transportation of larger rails (especially when rails have got to be shipped).
3. The width of the rail joint gap to be provided for rail expansion under temperature changes.

Experience gained with long welded rails has shown that the size of the rail joint gap, that has to be provided, is really independent of the length of the rail after a certain minimum length of rail has been reached.

The capacity of rolling mills has already been increased, within limits. The L. N. E. R. have, as stated already, standardized the 90-foot rail for use on their main lines, and have recently rolled 100 lbs. sections of rails 120 feet in length. Many of the rolling mills working to-day with modern machinery can roll a billet 4 tons in weight, which after the usual rejections, will give a rail 180—200 feet long.

The limitations of inland transport have been overcome during recent years to such an extent that the Delaware and Hudson Railroad in the U. S. A. has transported a rail **1,482′** long over flat trucks operating around 13° curves. But when rails have to be shipped, the maximum permissible lengths are definitely limited. Every country has now got its own rolling mills, and the difficulty of transporting very long rails by sea can be avoided. In deciding the lengths of rail to be used, care should be taken to see that the vibrations due to rail joints do not *synchronise* with the individual vibrations, set up in the rolling stock itself, as the cumulative effect of the two would be disastrous both to the rails and to the rolling stock.

Welding rails.

The lengths of individual rails *as laid* in the track have been greatly increased by welding and amongst the longest of such rails may be mentioned the rails 9,030 feet used in Braiditza tunnel.

The practical application of the welding of rail ends to form long unbroken lengths of rails, and the resulting reduction in the number of rail joints used in the track, though comparatively recent in its origin (1932) has been used extensively in most of the railways in the world. The South African Railways have 121 miles of their track laid with welded rails about 84 feet long; the Delawar and Hudson Rail road has six miles of welded track with continuous lengths ranging from 273′—6,900 feet.

The fish plated rail joint, whose maintenance accounts for more than 20—25 per cent of the total permanent way maintenance bills, is defective in the respects enumerated below :—

1. The fish bolts require to be tightened constantly.
2. The fish plates often get broken and require replacements.
3. The fish plates are not quite as strong as the rails they connect and bend more than is desirable, thereby resulting in hogged and low joints demanding constant attention.
4. The gap between the rail ends breaks the continuity of the wave of flexure caused by a rolling load, which results in increased wear of the rails at the ends and produces battered rails.
5. The effects of such batter are often cumulative and apart from reducing riding comfort, result in increased wear and tear of the rolling stock on account of the increased hammer action.

In their attempts to minimise these ill-effects and reduce maintenance costs, permanent way maintenance engineers cut away the battered ends of rails, reholed them and brought them together; fitted new fish plates and bolts, put in spring washers to prevent the bolts getting loose; used improved and

stronger fish plates, and shims to assist worn fish plates in counteracting rail batter. But they found in none of these methods a real cure. It was under such circumstances that the welded rail joint made its appearance and did away with the gap between the rails, and the consequential entourage of fish plates and fish bolts, joint sleepers, etc., at least in so far as they were used as the means for providing the necessary connection between rails.

Long welded rails have been tried :—

(a) on the electrified and the non-electrified sections,

(b) in places where the traffic is very dense and where traffic is light,

(c) on the straight and on the curves,

(d) on sections with axle loads both light and heavy,

(e) on sections with speeds ranging from 15 to 115 miles per hour, and

(f) both under the shade as well as in the direct heat of the sun's rays.

Wherever tried, they have stood the test of time extremely satisfactorily.

The lengths of rails welded vary from 72′—9,030 feet and in all these cases of welded rail joints no trouble whatever has so far been experienced provided the weld has been made satisfactory. Most of the railways have had their welding work done by contracting firms experienced in the job. Amongst those who have done their own welding may be mentioned the Delawar & Hudson Railroad which has some of the longest lengths of welded rails in the world. This railway has, as mentioned earlier, succeeded in conveying rails 1,482 feet in length, along a 13° curve on flat trucks and has unloaded the same with the help of a small crane.

The French railways are experimenting with welded rails 99′ 6″ long and the Egyptian railways with rails nearly 3,000 feet long for their goods sidings.

Process of welding.

The three main processes adopted for welding rail joints are :—

1. Fillet welding.
2. Thermit welding.
3. Resistance welding.

Fillet welding.

The first attempts made to weld rail joints were with the electric arc using special electrodes to suit the purpose. In the very first instances the fish plates, bolts and nuts were left in the joint, the welding being effected by fillet welds along the fishing surfaces. This method however was not an unqualified success as it was found that the welds gave way under load. The next attempt was made with sole plates under the flanges of flat footed rails, which were welded on to the flanges by fillet welding. This too was not a success as the sole plate invariably broke through the joint. Later on the above two methods were *combined* and this is now the standard practice on the South African Railways where nearly 21,000 joints have been welded by this method. The Italian Railways have also tried this method and prefer it to the other methods because of its lower cost. The Japanese Railways who have tried this method, namely the combined fish and sole plate welding by means of an electric arc, are not satisfied with it and prefer resistance welding to both this and the thermit welding process. It is interesting to note that no railway has, so far, tried on an extensive scale fish plate and sole plate welding with oxy-acetylene flame.

Thermit welding.

Thermit welding is the most widely used process of rail welding. It is popular in England, the United States, France, Austria and Germany. In Germany alone a million joints have been welded by this process.

In the thermit process of welding (more correctly the alumino-thermic process), the property of aluminium which, while easily combining with the oxygen held in chemical composition by metallic oxides, liberates the free metal thereof and the

resulting exo-thermic is made use of to produce the necessary weld metal to fill in the gap between the rails.

This reaction is represented by the equation

$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe +$ a large amount of heat.

The temperature usually attained is of the order of 3,000°C. To bring about this reaction, aluminium and ferrous oxide are used in a finely pulverised form so that the contact may be as intimate as possible between the constituents, and then are touched off with a suitable ignition powder. The latter once ignited starts the reaction which proceeds quickly throughout the entire mass of the mixture. The high temperature produced in this reaction is taken advantage of for the production of steel at any predetermined composition in a liquid state, and also to the softening of rails to such required degree as will readily combine with the molten steel and entirely fill the gap between the two rails. As there are no gases produced in the reaction, the heat is applied very effectively to the desired spot.

Thermit welding may be either :—

1. Fusion welding.
2. Compression welding.
3. A combination of the above two.

Fusion welding.

This is effected by filling up the gap between the rail ends by molten steel produced by the alumino-thermic reaction into a mould surrounding the joint, and allowing the molten metal to combine with the rail ends and set.

The apparatus required is extremely simple and consists of :—

(1) a suitable sand and compressed magnesia mould,

(2) a crucible to hold the products of reaction,

and (3) a bracket to hold the crucible in position.

A special portable petroleum blow pipe is also required to preheat the joint before the application of the weld metal and to obviate any chances of chills. To make the weld, the fish plates, fish bolts and nuts are removed and the rail ends are cleaned by

a wire brush and the mould applied in position. The flame from the blow pipe is then applied inside the mould. Apart from the heating effected, the flame also plays the part of a reducing agent removing the last traces of oxidation from the surfaces to be welded. After the rail ends are brought to a cherry red temperature, which is usually done in 15 to 20 minutes of heating with the blow pipe, the crucible is brought into a convenient position above the joint from which the molten metal can be tapped in a bracket clamped in that position. The reaction is then started just 3 to 4 minutes prior to the pouring in of the metal. The blow pipe flame is then removed and the molten metal tapped in by the opening of a cock in the bottom of the crucible. The iron runs into the gap between the rails and welds them, and also forms a collar all around the joint which is finally ground off. Seven minutes after the molten metal has been poured into the joint the mould is removed and the collar chipped and properly ground off. Finishing by grinding leaves a clean and level surface.

The compression method.

In this method no preheating is required, but a strong screw clamp is fixed to the rail ends to impart the final pressure required to effect the weld. The clamp consists of two steel frames fixed together with two large tightening screws which must be able to withstand a powerful pull exerted in the drawing of the frames together. The frames are fixed to the rail by screw hooks and grip the rail as in a vice. It is essential to see that the gripping is tight enough to prevent any slipping.

The weld is made as follows :—

The fish plates and bolts are removed, and the keys and other fastentings binding either rail throughout their length are also removed to permit freedom of movements to the rails. The screw clamp is then fixed in position and the rail ends are thoroughly planed by means of a revolving cutter with the two-fold object of cleaning the butt ends and rendering them plane, parallel and free from oxide. The rail ends are then adjusted to true level and brought firmly together. The contour of the joint is then carefully caulked to avoid any air getting in between the butt ends during welding.

When the joint is thus ready for welding, the sand moulds are adjusted in such a way that they have a calculated span between their walls and the rail section. The crucible is then placed above the mould, with the requisite amount of alumino-thermic compound, and the reaction started by igniting it. As soon as the liquid is ready, it is decanted into the mould. In order that the heat of the molten metal may penetrate properly into the moulds, 3 to 4 minutes are allowed after pouring in of the molten metal and the application of the pressure by the screwed frames. The butt ends are tightened as fast as they can be brought together by means of large spanners. The weld is then made and the mould and the frame are removed and the collar around the butt joint, which is still red-hot, is chipped and ground off. As the metal is welded by being upset, there is usually a boss formed at the joint which requires to be carefully ground off to the original section of the rail.

The combined process.

The combined process is, as its name suggests, a combination of the foregoing two processes. A thin soft iron plate shim is placed between the butt ends of the rails, which are then brought together, and the soft iron plate melts and dissolves a portion of the carbon from the rail ends during the weld and assists the rail in getting properly welded. The one other difference between the combined process and the compression process is that in the combined process the metal from the crucible instead of being decanted is tapped from the bottom of the crucible as in the fusion process which means that the steel comes in first and the slag later. But for these differences the combined process is nearly the same as the compression process.

Comparison of alumino-thermic processes.

The fusion method is the simplest and the cheapest and can be employed even in the case of battered rails as the molten metal can be used to build up the depression at the rail ends. It was originally feared that the weld metal bridging the gap between the rails being softer than the steel of the rails, a certain amount of cupping would occur at the welded portion, while in use, but experience has belied this fear. This method is quicker than the other two.

The combined process gives the best result and is particularly applicable when high carbon steels have to be welded. It is however costlier and cannot be successfully used in the case of rails with battered ends. Moreover the rails being brought together eventually shorten the track and the gap so caused requires to be made up. It therefore remains to be seen if this method with all its extra cost will justify itself.

Resistance welding.

In this, the rails to be welded are butted against each other and a heavy current passed through them. They are then slowly separated till an arc is produced which fuses the metal near the ends of the rails. The current is then shut off and the ends are brought together under great pressure which results in their being welded butt-wise. The metal is naturally upset at the weld and the excess requires to be ground off.

The plant required for this type of welding is large and heavy and not portable. The rails requiring to be welded have to be brought to a central depot and retransported to the site. This method cannot therefore be used for welding very long rails without having to face the difficulties of transportation. So far as the welding part of it goes, however, this method is decidedly cheaper than thermit welding but becomes costlier on account of the extra transportation charges. The plant itself is costly and the outlay thereon can be justified only if there are at least a hundred thousand joints to be welded. It would be important to mention here two outstanding features of resistance welding. The Delawar and Hudson Railroad have recently constructed a portable resistance welding set which enables them to weld rails *at site* by the resistance method. The railway has also conveyed a 1,498′ long welded rail, welded by resistance welding, on flat trucks along a 13° curve and unloaded them at the site by a small crane and labourers working with crowbars.

As far as efficiency alone is concerned both the thermit and the resistance processes of welding have proved to be equally successful although in a few instances on the Southern Railway thermit fusion welding has shown slight hollows in the welded metal.

The success of the electric arc welding of fish plates and sole plates to the rails, although proved on the South African and the Italian Railways by the large number of joints that have been welded by this method and stood up the test of time, is still doubted by many railways on the continent, Japan and America where it has been tried and found a failure.

Lengths of welded rails.

Length of rails welded varies from 72′ on the Japanese railways to 6,900′ on the Delawar Hudson Railroad. From the advantages to be had from welding rail joints, it would appear that welding them to the longest possible lengths would be the best. But herein railway engineers came across the great difficulty of making suitable provision for the expansion of the rails due to temperature changes. Expansion joints were originally tried and found to be costly and difficult to maintain and thus most of the gains to be had from welding were offset by the extra cost of the expansion joints. Experience has however shown that these long welded rails ranging from 72′ to 6,900′ did not expand, even under very wide temperature variations ranging from 100°F. to 150° F. any more than what a normal 42′ rail would have expanded. The explanation for this is not far to seek, in that these long lengths of rails are prevented from freely expanding and contracting by the track fittings that bind them to the sleepers.

It may however be noted that such prevention of expansion of rails results in the rails being internally stressed and often to as large an extent as 6 to 8 tons per square inch. This naturally impairs the strength and efficiency of the rail as a whole. There are two ways of combating this : One is to use a heavier rail so that the stress induced in it by the axle loads of the trains traversing it and these extra stresses due to temperature fluctuations are together within the permissible range of stress for the material. The second method is to use rails with a higher tensile strength so that the permissible working range is correspondingly raised.

It may however be noted that with the fish plated joint, whose strength is only 30—50 per cent of the rails which it connects, the extra strength of the rail to withstand greater stress, over and above the strength of the fish plates is of no practical use as long as this weak spot remains in the track.

The above presumption has been confirmed by the experiments conducted on track stresses by the Central Standards Office of the Railway Board. Such being the case, the elimination of the fish plated joints and the provision of a track of uniform strength by the welding of the rail joints even though it results in a structure the permissible range of whose strength for resisting the stresses due to train loads is less than that of the original rail due to expansion stresses that are induced therein on account of temperature fluctuations, do not in any way make it less strong than the original track with fish plated joints.

Some Engineers are still of the opinion that the question of welding should above all be decided by the safety resulting from the stability and equilibrium of the track at all temperatures. This stability, they believe, can be obtained only when rails, no matter however long are, free to expand. The use of long rails according to them is subordinated to the possibility of having rail ends free to move so as to absorb the expansion occurring at high temperatures. This complex question, they are of opinion, does not seem insoluble provided the joint, that is able to deal with considerable changes in length, can be used. The above opinion is quoted to be adjudged in accordance with its worth.

Financial aspects of welding rail joints.

The welding of a rail joint has so far cost 1·5 to 13 times the cost of fish plated joint depending on circumstances under which it has been used. In countries like America, South Africa, Germany and Japan where the welding of rail joints have been extensively used, the cost of welding each rail joint varied from 1·5 to 3 times the cost of unbonded fish plated joint. But in countries like Great Britain, where welding is still in an experimental stage, the cost of welding each joint has varied from 4 to 13 times the cost of an unbonded fish plated rail joint. Even in these countries in station yards, where track circuiting is in existence, the cost of a welded joint is only 1·3 to 4·5 times of a bonded fish plated joint.

Coming next to the savings to be had from welding rail joints it is rather premature to fix a monetary value upon the advantages to be had therefrom. It is, however, expected that welding of these rail joints would give a return of not less than

a hundred per cent annually on the capital invested in the welding of each joint, especially in countries where the cost of welding each joint is brought down by extensive use to a reasonably low maximum limit.

Testing and inspection of welded rails.

The laboratory tests performed on welded joints are :—

1. The tensile test.
2. The impact test or tup test.
3. The bend test.
4. The microscopic examination of texture.
5. Special tests such as electrical conductivity test, Berry grain gauge detector, and X-ray examination, etc.

The tup or impact test and the bend test are done by almost all railways.

The Delawar Hudson Railroad performs all the above five tests. Under item 5 they have continuous deflection test to destruction and the Berry detector test. The majority of British Railways perform no test at all. South African Railways have the impact test, bend test and microscopic examination. Japanese Railways test welded joints under service conditions to destruction.

Field tests consist of a systematic visual examination of the rail joint and periodic reporting on their behaviour. The American Railways in addition take the Brinnel hardness number of the weld metal.

The inspection that is being carried out consists of noting the expansion these long rails undergo at suitable intervals of time. In addition all railways arrange for a daily inspection of these welded joints to see whether they are intact or fractured.

Except for the Delawar Hudson Railroad none of the other railways have a specification for welding of rails.

Defects and difficulties experienced in the maintenance of welded joints.

In some instances slight hollows on the surfaces at the welds have been noticed. On most railways fractures of welded rails at welds are comparatively rare. This is an experience in which all the railways that have tried welding of rail joints share. This is probably to some extent due to the heat treatment to which some of the railways subject the welded joints before allowing trains to pass over them. The South African Railways, however, report 107 fractures in 21,170 welds. Out of these 107 fractures, 67 are due to cold straightening of badly battered rails before welding. Thus the rest 40 fractures in 21,170 welds are less than 0·2 per cent. The only other case of failures that are reported are from Delawar Hudson Railroad and No. 8 in 1,400 welds.

No difficulty has so far been experienced by any railway system in maintaining these welded joints. It was feared that with these long welded rails, the expansion due to temperature variation would result either in undue buckling of the track or in the necessity for the provision of longer rail gaps. But from experience gained over many countries and in almost all different kinds of climates it is noticed that such fears are entirely unfounded and that rails even as long as 1 mile do not expand any more than what a 36′ or a 42′ rail would ordinarily expand.

Summing up, the advantages to be had from welding rail joints are as follows:—

1. Saving in labour of maintaining joints.
2. Longer life of rail due to elimination of joint batter.
3. Labour saving in laying of rails due to increased life of rails.
4. Better conductivity in track circuits and the elimination of the necessity for the provision of battered joints.
5. Saving in maintenance of rolling stock and motor power.
6. Riding comfort as a result of smoother and evener track.

7. Saving in maintenance of alignment and surface by practical elimination of creep and its effects.

8. Less dislocation of or interference to traffic due to less frequent renewals.

9. Rail ends and rails of different lengths can be used.

10. Heavier axle loads and greater speeds can be permitted.

The one main disadvantage likely to result from the welding of rail joints is the increase in fibre stress due to the restricting of the linear expansion consequent on temperature changes. This may at worst offset the advantage last named above.

The second and probably not quite a serious defect in welding rail joints is its incapacity to stand up to the tup test. Tests performed by Dr. R. N. Chowdri, Assistant Metallurgical Inspector, Tatanagar, have shown that the strength of welded joints, as can be inferred from their resistance to impact, is low and extremely variable. This is due to the fact that brittle and hard material is produced near the weld zone. This brittle and hard material zone extends for nearly an inch on either side of the weld, but may perhaps be improved by heat treating the welded portion after the completion of the welding. Even if such heat treatment were not done, it requires to be investigated if it is absolutely essential to have the welded joints withstand the tup test, before using them on main lines carrying heavy and fast traffic. Experience which we have so far had from various countries of the world using welded joints, shows that there have been very few failures of the welded joints and as there are millions in service it may be assumed that it is safe to use these welded joints on main lines carrying heavy and fast traffic even though they may fail to stand up to the tup test.

Thus from what has been stated above it may be seen that welded rail joints will find universal application and gradually replace the fish plated rail joint in the near future.

It would be seen from the foregoing that there is immediate scope for the welding of rail joints on Indian Railways by the combined thermit process for experimenting.

1. In tunnels where packing is difficult and never satisfactory and the temperature range is very much less than where the track is exposed.
2. Under all covered roofs.
3. On bridges; this will reduce the impact effect of the moving loads. In such cases it is probably advisable to take the additional precaution of providing an expansion joint at each end of the rail.
4. In localities on the straight track, where the maximum temperature range is comparatively small, specially if the lengths of welded rails are limited to 84′ and provided with 5/8″ expansion gap on duplex joint sleepers fitted with specially reinforced fish plates, and spring washers.

It may be necessary at the beginning for Indian Railways to get their welding work done through contractors who have had sufficient experience of the work in other parts of the world. In the coming cold weather the experiment of welding of about one thousand joints is likely to be carried out on the G. I. P., E. I., and N. W. Railways to see whether the welding of rail joints will prove as successful on Indian Railways as elsewhere. The results of these trials may have a large bearing on future permanent way policy.

Manufacture of rails.

In order to stand up against present day working conditions, railways have had to equip their main lines with high grade materials, capable of standing the increased loads and speeds of their revised traffic requirements. Amongst these, manufacture of rails has received attention on all main line railways who concentrated their efforts in improving the quality of rail steel and post-rolling treatment that is given to rails so as to make them stronger, more resilient and wear resisting.

Most of the railways specify during manufacture,

(a) a minimum cross sectional area of the ingots,

(b) the lowest possible final rolling temperature—generally not greater than 850°C,

(c) a sufficient top discard of the ingots nearly 12—20 per cent for exclusion of piping.

Many railways prefer cambering of rails while hot, so that they may get straight when they are cool. On the Indian Railways it is proposed to specify that if rails are cambered after cooling, the camber should be 'reverse camber' *i.e.* when laid with head upwards, the centre of the rail will be lower than the ends. This will minimise any likelihood of low joints.

Some railways on the Continent require a guarantee against break for 5 to 6 years for all their rails.

Process of manufacture.

The following processes of manufacture are recognised:—

(a) Thomas.

(b) Siemens—Martins Acid open hearth.

(c) Duplex.

(d) Acid Bessemer.

(e) Basic open hearth.

Indian Railways Standard Specification permits of processes b to e above.

French railways prefer mostly 'Thomas' process although Rails made of Martin and Acid Bessemer processes are also made use of. On all other railways on the Continent Siemens-Martin open hearth or Thomas process are used. British Railways prefer Martins' open hearth process, while American Railways prefer Duplex steel.

Chemical analysis.

Almost every railway specifies the chemical analysis for the rails required by them. The following 7 types of rails are used by the various railway administrations in the world.

1. Ordinary carbon steel rails.
2. High carbon rails.
3. Medium manganese rails.
4. High manganese rails.

5. Chrome rails.
6. High chrome rails.
7. Nickel-chrome rails.

High chrome, High manganese, and Nickel-chrome rails are quite costly and as such are used only in locations where the wear is exceptionally high.

The chemical composition specified by Indian Railways is as follows:—

Carbon steel—Basic open hearth or Duplex.

Element.	Nominal weight per yard.		
	50 lbs. and under.	60—90 lbs. inclusive.	Over 90 lbs.
	%	%	%
Carbon	0·50 to 0·60	0·55 to 0·68	0·58 to 0·68
Silicon (Minimum) ..	0·05	0·05	0·05
Manganese	0·60 to 0·90	0·65 to 0·90	0·65 to 0·90
Sulphur (Maximum) ..	0·05	0·05	0·05
Phosphorus (Maximum) ..	0·06	0·06	0·06

Acid open hearth process.—All sections.

Element.	%
Carbon	0·50 to 0·60
Manganese	0·80 Max.
Silicon	0·10 to 0·30
Phosphorus & Sulphur ..	·06 } ·06 } Max.

Acid Bessemer Process.—All sections.

Element.	%
Carbon	0·45 to 0·55
Manganese	0·90 Max.
Silicon	0·10 to 0·30
Phosphorus & Sulphur ..	0·06 Max.

Chrome steel—All sections

Element.	%
Carbon	0·42 to 0·53
Silicon (Minimum)	0·05
Manganese	0·65 to 0·85
Chromium	0·75 to 1·00
Sulphur (max.)	0·05
Phosphorus (max.)	0·05

Medium Manganese steel.—All sections.

Element.	%
Carbon	0·45 to 0·55
Silicon (Minimum)	0·05
Manganese	1·10 to 1·40
Sulphur (Max.)	0·05
Phosphorus (Max.)	0·05

*The combined carbon and manganese content shall not be less than 1·65 per cent.

British Railways.

Carbon Rails.

Element.	Process of Manufacture.		
	Acid open-hearth.	Basic open-hearth.	Acid Bessemer.
	%	%	%
Carbon for rails above 50 lbs. per yard ..	0·50 to 0·60	0·55 to 0·68	0·45 to 0·55
Carbon for rails below 50 lbs. per yard ..	0·45 to 0·55	0·50 to 0·63	0·40 to 0·50
Manganese	0·70 to 0·90	0·70 to 0·90	0·70 to 0·90
Silicon	0·10 to 0·30	0·10 to 0·30	0·10 to 0·30
Phosphorus (Maximum) ..	0·06	0·05	0·06
Sulphur (Maximum) ..	0·06	90·0	0·06

Medium Manganese.

Element.	Process of Manufacture.		
	Acid open-hearth.	Basic open-hearth.	Acid Bessemer.
	%	%	%
Carbon for rails above 50 lbs. per yard ..	0·45 to 0·55	0·50 to 0·60	0·40 to 0·50
Carbon for rails below 50 lbs. per yard ..	0·40 to 0·50	0·45 to 0·55	0·35 to 0·45
Manganese	0·90 to 1·20	0·90 to 1·20	0·90 to 1·20
Silicon	0·10 to 0·30	0·10 to 0·30	0·10 to 0·30
Phosphorus (Maximum) ..	0·06	0·05	0·06
Sulphur (Maximum) ..	0·06	0·06	0·06

America. Open Hearth Carbon steel rails.

Element.	Weight in lbs. per yard.				
	50—69	70—84	85—100	101—120	121—140
	%	%	%	%	%
Carbon ..	0·50 to 0·63	0·53 to 0·70	0·64 to 0·77	0·67 to 0·80	0·69 to 0·82
Manganese	0·60 to 0·90	0·60 to 0·90	0·60 to 0·90	0·70 to 1·00	0·70 to 1·00
Phosphorus (Max.) ..	0·04	0·04	0·04	0·04	0·04
Silicon ..	0·10 to 0·23	0·10 to 0·23	0·10 to 0·23	0·10 to 0·23	0·10 to 0·23

France. Open Hearth process.

Carbon	.. ..	0·45 per cent.
Manganese	.. ..	0·90 per cent.
Silicon	.. ..	0·125 per cent.
Phosphorus	.. ..	0·07 per cent maximum.
Sulphur	.. ..	0·04 per cent maximum.

Rails used on American Railways contain more carbon than those used on Indian Railways or British Railways, but the phosphorus content is limited to a maximum of 0·04 per cent which is probably due to the fact that there have been more breakages of rails on American Railways than elsewhere. It is interesting to note that rail fractures on Indian Railways are comparatively few which may probably be accounted for by the fact that the axle loads run on Indian Railways are lighter than those which the sections can stand. It may also be due to the fact that inspection of rails for Indian Railways has always been satisfactorily done.

Inspection and tests.

Inspection of new rails for purchase purposes is performed both during manufacture and after, and consists of:—

1. Informatory tests.
2. Tests for elimination of defective rails.

Informatory tests are usually performed on a small percentage of the rails ordered or purchased and are sometimes destructive in character. A certain amount of inspection, usually micrographical and analytical, is carried out during manufacture.

The usual tests performed are :—

1. The Tup test otherwise known as drop test or falling weight test.
2. The Hammer test.
3. The Pendulum impact test.
4. The Hardness test.
5. The Tensile test including percentage of elongation.
6. The Bend test.
7. Microscopic examination.
8. Chemical analysis.
9. The Resilience test.
10. The Wear test.
11. The Etch test.
12. The Microphone test.
13. Imposition of supersonic waves.

Of the above items, 1 to 10 are informatory tests and are performed on selected rails on a percentage basis. Items 11, 12 and 13 are usually performed on all rails for the elimination of the defective rails.

Tests 1 and 6 are performed on the full rails and are destructive in character.

The Indian Railway Standard Specification No. T-12 details following tests :—

1. Chemical analysis.
2. Tup test.
3. Hammer test.

British Standard Specification No. 11 used by British Railways specifies :—

1. Chemical analysis.
2. Tup test.
3. Tensile test.
4. Pendulum impact test.

American Railways specify :—

1. Chemical analysis.
2. Tup test.
3. Brinnel test.
4. Tensile test.
5. Wear test by spindle system.
6. Microphone test.

On American Railways the microphone test is used to detect shatter cracks which occur while the rails are cooling, which eventually develop into fissures.

Shatter cracks are also detected by head down drop test.

Repeated drop test till destruction is not considered as reliable as slow bend test till destruction, for the energy in the bend test is applied under greater control. Often in the drop test, shatter cracks easily develop and break which ordinarily will not be serious in the track.

It may be said that in the bend test there is no speed in the application of the energy to represent the impact imparted to the rail by the rolling of heavy wheels at high speeds but it is considered that testing of rails at speed is not quite so necessary. Thus it is expected eventually that the bend test will replace the tup test.

In America, where rail fissures have been most common, it has been found that with improved maintenance, well kept rolling stock and good selection of rails, the number of failures due to fissured rails have of late become considerably reduced.

Heat treatment.

In recent years heat treatment of rails as a means of improving the characteristics of the metal in ordinary metals has been greatly adopted on many railways. Some of them are considering the question so as to make it obligatory for all rails supplied to them being heat treated.

Heat treatment generally consists of heating the rail in a muffled furnace or in the open immediately after it leaves the

mill to a known maximum limit of temperature, and cooling the rail so that the resulting product is hard without being brittle.

Uniform hardening (by quenching in air or water) under accurate control restores plastic flow and reduces end batter. Heat treatment in general increases strength, toughness and ductility. Some railways prefer heat treating, only the head of the rails and some others require heat treatment of only the ends. In all cases of heat treatment it is really the rate of cooling and the control exercised therein that is most important. According to the degree of hardening and subsequent tempering, the structure of the outer skin of the head becomes either martensitic or sorbitic, a feature which finally governs the quality of the whole rail.

The processes in use are :—

1. The sand-berg process, which consists of heating of the whole rail and cooling the rail progressively under control.
2. Processes at Neuves—Maison's works and at Providence works on the Continent which consist of the heat treating head only by quenching it in water.

The latter method has the advantage of hardening the head at the correct temperature and annealing the remainder of the section, but is rather costly. It remains to be seen if this method with its extra cost is financially justifiable.

Some railways use heat treated rails in places of dense traffic or extra wear such as on curves, points and crossings and locations where there is constant braking and slipping. Many railways subject heat treated rails to severer testing.

It is too early to comment on the financial success of heat treated rails but the indications, computed on the present rate of wear exhibited by them, are that there will be a substantial increase in their lives and will give a net return on capital that will amply justify the investment.

Insisting on heat treated rails makes inspection an easier matter for then it will not be necessary to worry about small cracks and flaws in the head, which, while being dangerous in a

brittle material, are not so in a ductile material. Heat treated rails will be less destructive on the rolling stock as well as on the fish plates.

Heat treatment of hard steel rails.

In many instances hard rails have been found to wear much quicker than ordinary mild steel rails which is perhaps due to the fact that the resilience factor of hard steel rails is very much less as compared with their strength. Hard rails will not be an advantage to use unless the resilience factor both at the middle of the head and the bottom of the ingots from which the rails are made is not less than 400 feet lbs. per sq. inch. In the case of hard rails it is very much more important that all piping should be completely removed in the billets before they are rolled into rails. It has been found that the wear of rails in general is due not so much to the tonnage carried or the softness of the steel but to the fact that the metal was not properly deoxidised. This absence of complete deoxidization causes cracks in the rail foot and star cracks in bolt holes. Micrographical examination shows insufficient deoxidization as clearly as it does in the case of any lack of homogeneity in the structural formation. Thus in the case of hard rails heat treatment which makes it more resilient is very much more essential.

Brunorizing is a recently patented process of heat treatment in which the entire structure of the rail is altered and reformed. It relieves the rail completely of all internal stresses and increases the ductility of the metal.

Special steels.

Many railways are using high manganese steels, with 14 per cent manganese content, or Nickel Chrome steel for points and crossings. Copper Chrome steels are used extensively in tunnels and other damp places for preventing rusting action on rails. The P. L. M. Railway in France is trying a copper steel with ·3% copper.

Jugoslavian Railways are using rails with ·2% molybdenum and 1·8% manganese. This steel has a tensile strength of 57·1 tons per square inch and a minimum elongation of 10%.

No railway has however found it economical to use any special steel on the ordinary track.

Rail fissures.

A rail 'fissure' is a localised soft spot in a rail which ultimately brings about the failure of the rail. Rail fractures due to fissures have been very common in America and have been the subject of considerable research and study in that country.

The genesis of an internal fissure is nearly always a shatter crack in the centre of the head of the rail, but all shatter cracks do not develop to be fissures. High silicon content is attributed to be the cause of shatter cracks. In America, where rails have suffered most from fissures, electric detectors have been designed to detect fissures in rails that are actually in the track. A systematic examination of most of their main lines has been conducted with this electric detector to eliminate all doubtful rails from the track.

It is noticed that heat treatment prevents to a great extent the formation of shatter cracks and the consequent failure due to fissures.

Reviewing the practices regarding rail design and manufacture the following suggestions are put forward for adoption on Indian Railways :—

1. The standard length of rails may be conveniently increased to 60′ with heat treated ends, and may be laid with a maximum expansion gap of 5/8″.
2. It will not be found necessary to use a rail heavier than the 90 lb. F.F. B.S. revised section rail on any section of the Indian Railways.
3. Medium manganese or chrome steel sorbitic rails should be used on all curves sharper than 1° and for points and crossings.
4. The specification for rails may be modified to include the following tests :—
   (1) Chemical analysis.
   (2) Pendulum impact test.
   (3) Brinnel hardness.

(4) Tensile test (includes percentage elongation).

(5) Bend test.

(6) Microscopic examination.

Rail joints.

As has already been stated, the joint, the assembly of the two rail ends butted together, is the weakest link in the track. The running surface of the rail head is interrupted and the shock set up as each wheel runs over the gap loosens the track sound about the joint and ultimately wears and deforms the rail. These drawbacks become more marked as the weight and speed of the vehicles traversing the track increase.

The only type of rail joint in common use is the fish plated rail joint, wherein, a pair of fish plates bolted to either rail by bolts passing through the web of the rail, bear under the head and foot of the rail. The two main types of fish plated joints used are the suspended joint where the joint lies between 2 sleepers and the supported joint where the joint rests on supports. The suspended joint is more commonly used but several railways in the United States have adopted the supported joint. The railways that use the supported joint use soft rubber packings underneath the joint for making it more elastic and less rigid than it would otherwise be.

Joint sleepers sustain comparatively greater loads than intermediate sleepers, and if it be a supported joint, the joint sleeper bears the greater part of the load at the joint and is consequently apt to yield. On the other hand in the case of the suspended joint, the shock of the wheel at the rail joint is shared between the two adjacent joint sleepers and thus track maintenance is easier. For suspended joints it is good practice to lay the two adjacent sleepers as close as possible without interfering with the facility for proper tamping. On the North Western Railway the joint sleepers are brought as close together as 1″ and the tamping is not in any way affected. On some railways a double sleeper is used at the joints but even here the actual joint is not supported. (See Duplex joint sleeper described later on). On some other railways the sleepers next to the joint sleepers are also spaced closer than the ordinary sleepers such as in the centre of the track.

Some railways adopt the random joint, *i.e.*, the joint situated at random without any regard to the relative position of the sleepers. The random joint should be adopted only on track laid with very heavy rails on closely spaced sleepers.

In the United States of America staggered (alternate) joints are used while in other countries opposite joints are the standard. In India staggered joints are used only on curves. The main disadvantages of staggered joints are that the number of shocks sustained by a vehicle are doubled in any length of the track and also require more sleepers if the same close spacing at the joints have to be adopted. The advantage to be had is that the intensity of the shock is very much reduced, and considering both the pros and cons it is suggested that staggered joints should be used only on track with very close sleeper spacing and with joints of great rigidity like the track of the railways in the United States of America.

Fish plates.

Many railways make the pair of fish plates have nearly the same section as the rail they connect.

The Japanese Government Railways have the following ratio

Upto 60 lbs./yard	..	0·834
Upto 75 lbs./yard	..	0·859
Upto 100 lbs./yard	..	0·890 (flat fish plates). 0·937 (angle fish plates).

The area of a pair of fish plates approaches that of the rail as the weight of the rail increases. In the United States for 110 lbs. rails this ratio is almost 1·00. On Reading Railroad for the 130 lbs./yard rail this ratio is 1·30.

The fish plates to be used for track carrying heavy loads at high speeds should be designed with as much sectional area as possible. The experiments performed by Mr. Gelson under the Central Standards Office for Railways have conclusively shown that in most cases the weakness of the track is due to weak fish plates. While in an ordinary track each fish plate has only to take up a 1/4 of the bending moment of the rail, the

modulus of section being comparatively much less than that of the rail, the stresses induced in it are consequently nearly double of that in the rail. The stresses induced in an unsymmetrical section of fish plate is much more than that induced in a symmetrical section. Besides, the unsymmetrical fish plate bends laterally under vertical loads and gradually moves from its position thereby causing undue dipping of the rail joint.

The Netherlands Railways introduced in 1928 a special cast iron chair so that the fish plates are only pressed against the fishing surfaces of the rails by and when the rolling load passes the joint. They however report that this design has not been found to be quite satisfactory.

Mr. Morgan, late Chief Engineer. N. W. Railway, designed a fish plate in which the fishing surfaces had contact with the rail only at the ends and at the middle. This too has not proved quite a success.

Some special fish plates such as 'Levaire' and 'Chevron' tried on the French Railways have also not been quite a success. The B. N. Railway has tried a fish plate in which the centre is thicker than at the ends. This has been a success but owing to rolling difficulties this has not been extensively used.

The Head free fish plate in which the fishing surface is at the corner of the head and not at the top has been tried but found to be not quite so economical as it was thought it would be. The length of the fish plate varies from 20" to 27" according as whether 4 bolts or 6 bolts are used. Recently some railways tried 2 holed fish plates 14" to 16" long but these were not found to be very satisfactory. Most railways however prefer the four hole fish plate nearly 18" to 20" in length.

Some railways have tried the use of shims along with fish plates so that these may be cast off and new ones replaced to take up the wear in the fish plates and keep the joint always high. The use of these shims has been quite a success.

The bending that occurs in fish plates is irrespective of their length, and the longer fish plates do not increase the rigidity of the joint nor decrease the pressure on the sleeper at the joint, and as such increasing the length of fish plates is not as effective as increasing their sectional area.

However with the use of longer fish plates with 6 holes the effect of loosened fish bolts is somewhat lessened, and the contact pressure between the rail and the joint is also less.

Fish bolts.

Usually the diameter over the shank is 15/16" and over the threads 1". But several railways use thicker fish bolts. A 1" diameter bolt is sufficient for any section of rail up to 100 lbs. per yard.

High chrome spring washers.

When a fish bolt works loose, the tendency is for the fish plate not to function properly and for the rail to get hogged. This is prevented by using high chrome spring washers which keeps the fish bolts always tight, and is consequently recommended for use on track where the speeds of trains exceed 70 miles per hour.

Width of the rail gap.

For ordinary unwelded rails, most railways provide a rail gap based on the formulae :

$$W = C. L. (T-t)$$

where C is the co-efficient of linear expansion of rails which is taken to vary from ·000001 to ·0000015,

L is the length of the rail in inches,

T the maximum temperature likely to be attained, and

t the temperature at which the rails are laid in the track.

In hot countries like the French West Africa, the expansion has to be provided for a range of 176°F. but ordinarily the provision for an expansion for 100°F., subject to a maximum of 5/8", would meet all the requirements of modern track design. English Railways work to a maximum expansion gap of 1/2" even for their 60' rails.

Experiments performed by Mr. Gelson of the Central Standards Office have given indications that the fish plates in the Indian track are highly stressed and that they consequently

need to be redesigned. While redesigning them it is suggested that the section of each fish plate may be made as symmetrical as possible and of an area at least 50% of the rail section which it is intended to connect. The length of the fish plate may be allowed to remain the same as that of the present Indian standard plate.

As regards the spacing of joint and shoulder sleepers the following suggestions are made :—

The joint sleepers may be brought as close as can be conveniently brought with the shoulder sleepers being placed 20″ apart centre to centre.

It is also suggested that for Indian conditions the suspended joint only should be used and that the staggered rail joint should be confined to curves only.

CHAPTER III

Sleepers.

Sleepers serve the double purpose of supporting the rail and keeping the gauge. In addition they absorb the lateral thrusts of vehicles. Thus it is evident that sleepers are also subjected to stresses which increase rapidly with the increase in the loads and speeds of the vehicles running on them.

Many railways have met the effects of these growing loads and speeds by increasing the number of sleepers per rail length so as to distribute the load over a greater number of sleepers and to improve the grip of the sleepers in the track.

Number of sleepers.

The general tendency all the world over is to increase the number of sleepers laid in the track. In addition to the number used on the tangents, French Railways use extra sleepers on curves. They also use an extra number of sleepers on formations with a poor soil. In North America most of the railways use 3,200 to 3,250 sleepers to the mile which is practically the maximum number that can be used in a track consistent with the minimum width between sleepers necessary for packing even with pneumatic and other power tools.

No. of sleepers used per rail length.

India	..	N + 3 to N + 5, *i.e.* 17 to 19 for a 42′ rail.
England	..	N + 4, *i.e.* 24 sleepers for a 60′ rail.
America	..	24 sleepers for 39′ rail.
France	..	30 to 33 sleepers per 18 metres. In tunnels and curves, 44 sleepers per 24 metres.
Continent	..	18 to 20 sleepers per 12 metres.
Japan	..	41 sleepers per 82′—¼″.

The remarkable difference between the sleepering in North America and the rest of the world is mainly due to the difference in axle loads. The number of sleepers used depends to a certain extent on the weight of rail used, a smaller number being used when a heavier rail is used. Japan provides for a sleeper depression of 0·28 c.m. Great Britain 0·34 c.m., and the United States 0·32 c.m. The rail pressure on the sleepers in the above three countries are 2,800 kg., 4,800 kg. and 4,500 kg. respectively per sleeper.

The Japanese Government carried out an investigation regarding the reaction between track maintenance and the number of sleepers to determine the most profitable number of sleepers to use. It has been found that it is most economical to use 15 to 16 sleepers for 33′ rail for their main line track. In this connection it may be stated that, whereas a certain number of sleepers is indispensable to support safely the loads coming on them, an extra number results in increased renewing and tamping cost and becomes uneconomical. Therefore it is essential that the number of sleepers should be correctly determined for each section of the track depending on the axle loads and speeds that operate on it.

When tamping is done by picks, the clear space between sleepers should at least be 14″. Anything less than this will make tamping difficult and makes the increase in the number of sleepers ineffective and uneconomical. In the case of C.I. sleepers, where the plates or pots are connected by thin steel tie rods, the number should be large enough to properly preserve the gauge, for the strength of these tie rods against buckling is comparatively small as compared with wooden sleepers.

Laying plan.

Many railways have a much closer spacing for their joint sleepers than for the intermediate sleepers. This spacing varies from 2″ to 10″. A few railways make their joint sleepers actually touch while at the same time providing for suspended rail joints. Some railways in addition to placing their joint sleeper closer than their intermediate sleepers provide for a closer spacing of the 2 or more sleepers next to the joint sleepers, though the closeness of the spacing of such sleepers is not necessarily the same as that for the joint sleepers.

Type of sleepers.

Nearly all the railways use on their main lines wooden sleepers which they definitely prefer to metal sleepers. The wooden sleeper is undoubtedly the best for high speeds because of its flexibility and the way it stands up under heavy loads. The considerations determining the choice of the type of sleeper used are technical, local or economical. For example, metal sleepers cannot be laid in places where they will be quickly destroyed by weather or other soil conditions. Nearly all the Western countries impregnate their sleepers with some preservative compound which extends the life of the sleepers in the track by at least 5 to 10 years.

Of the railways using metal sleepers the Great Western has used 500,000 steel sleepers and India has used nearly 10,000,000 sleepers of steel and cast iron. Very few countries use reinforced concrete sleepers. French railways have recently tried a reinforced concrete track in which the rails rest on thick 1" helical springs, which ultimately bear on a reinforced concrete longitudinal platform.

Wooden sleepers.

Most of the railways use hard wood sleepers for their main lines carrying heavy traffic and such of the railways, like Indian Railways that use soft wood sleepers, use steel or cast iron bearing plates for a proper distribution of the rail pressure and for preventing the sleepers being cut by the rail foot. The wooden sleeper is the most convenient form of sleeper for Bull-headed rails.

The dimensions of sleepers in use on various railways are :—

1. India .. 10" × 5" × 9'.
2. Britain .. 10" × 5" × 8'-6" and 12"×5"×8'-6" for joint sleepers.
3. United States of America .. 9" × 7" × 8'-6".
4. Continent .. 8" × 6" × 8'-6".
5. Japan .. 8" × 5½" × 7'-0".

The sizes are not exactly comparable as the gauges are different. In determining the sleeper dimension, one of the factors that should be taken into account is the rail pressure which varies from 10,000 kgr. to 16,800 kgr. on the various railways. It may however be said that the sleeper sizes used on British Railways are the most economical.

Wooden sleepers fail due to:—

(a) Failure at rail seat on account of cutting down due to

(i) water, sand, etc., getting in,

(ii) rail abrasion; and

(b) continued rail spiking.

It is noticed that in the case of soft wood sleepers bearing plates increase their life from 25 to 40 per cent.

Some 7 or 8 years back it was considered advisable on Indian Railways to use sleepers of the following sizes :—

9′ × 8″ × 6″

9′ × 7″ × 7″

9′ × 7″ × 6″

The arguments put forward in favour of adopting these sizes in preference to the existing standard 10″×5″ were:—

1. With the smaller width of sleepers a greater number can be used giving the same packing distance.
2. Greater depth means greater strength and stiffness.
3. 7″ min. is more than ample for supporting a bearing plate.
4. 10″×5″ sleepers were considered unsuitable for heavy loads.

Finally, however, the 10″×5″ sleepers were retained as standard for the reasons given below :—

1. Sleepers seldom if ever break by bending.
2. Increased number of sleepers do not correspondingly or substantially increase the capacity of the track to take greater loads.

3. Wider sleepers are necessary for proper distribution of stress on the ballast.
4. Greater width necessary for adjustment of spike holes.
5. Greater depth requires more ballast and more maintenance cost every time a sleeper has to be packed.

On the North Western Railway an experiment was recently made with interpolating sleeper cuts between full sleepers. They used 5 to 7 cuts with N to N -2 full sleepers and the experiment has been found fairly successful.

Treated sleepers.

Chemical treatment increases the life of wooden sleepers by nearly 5 to 10 years (30 to 60 per cent). The materials used for impregnation of wooden sleepers are—creosote, shale oil, copper sulphide and zinc chloride. Recently the Forest Research Institute, Dehra Dun, India, have found an aqueous solution of copper sulphate and arsenic that could be used by adopting the Ascu process. This process however has not proved an unqualified success as the preservative does not penetrate completely the entire section of the 10″×5″ Indian standard wooden sleeper.

Treated sleepers require special handling as they burn the hands of the users. It may be confidently surmised that in the coming 10 or 15 years treated sleepers will entirely replace the non-treated sleepers now existing in the track.

Steel sleepers.

On tracks, where speeds and loads are not very high, steel sleepers are sometimes used, being considered cheaper in the long run. Steel sleepers with pressed-up lugs have been found to fail at the rail seat because the section was not strong enough to withstand the static and dynamic forces imparted through the rail. This has been remedied by using steel sleepers with movable jaws which fit into holes punched in them. It is inconvenient to use steel sleepers on curves which require widening of the gauge. Steel sleepers with saddle plates, *i.e.* extra plates welded at rail seat, were tried but have not been

found to be very successful. Making a steel sleeper uniformly strong throughout means so much extra metal being wasted, but this appears to be the only feasible solution for the problem.

Recently one of the manufacturing firms in India has designed a metal sleeper, which they term a composite sleeper, in which another small section of the sleeper is imposed upon the original steel sleeper at the rail seatings. It is premature to say whether the composite sleeper will be a great success.

C. I. sleepers.

India is one of the few countries that use cast iron sleepers in large numbers. There are several designs in use but the design got out by the Central Standards Office No. C. S. T. 9, has been found to be the best and will be shortly standardized for use over all the railways in India. The two main defects with cast iron sleepers are their breakage during transit, laying etc., and the large number of fittings and separate parts that each sleeper consists of. Laterally it is not strong enough to hold the rail gauge.

The Central Standards Office has designed a key for fixing the rail on to the sleeper which can be used with almost all designs of cast iron sleepers used on Indian Railways.

Reinforced concrete sleepers.

These were tried some 10 or 15 years ago but have failed for two reasons. The concrete could not stand up to the pounding action of the traffic passing over it, and it was not possible to design proper fittings to connect the rail to it. With the modern methods of concrete control, the sleeper may be made in such a way as not to disintegrate as it did before, but the problem regarding the fitting still remains unsolved. During recent years mixed steel and concrete and wood concrete sleepers have been designed and tried but without success.

Duplex sleepers.

Mention should here be made of the Duplex or Double sleeper designed by the Central Standards Office for Railways in India, which is intended for use at joints. This is essentially a cast iron sleeper of nearly double the width of the ordinary

sleeper in which the rail joint supports the rails through a suspended joint, till the very last ½″ of it from the end. The main advantage of this Duplex joint sleeper is the increase of strength it affords the rail near the joint. Although it has been designed only in 1934, it has been extensively used on the E. I. Railway (India) and found quite a success.

Welded steel sleepers.

This type of sleeper is designed by welding bearing plates to scrap rails and is found quite useful for branch line work with lesser axle loads and speeds.

Concrete asbestos sleepers.

Before closing this subject of sleepers mention may also be made of concrete asbestos sleepers now being tried on the Continent. It is only a year since this type of sleepers have been laid in the track and as such it is too early to predict anything about their success.

On Indian Railways with joint and shoulder sleepers closely spaced, it will not be necessary to use any number greater than $n+4$ sleepers for 42′ rails and $n+6$ sleepers for 60′ rails if the latter are used. The type of sleepers to be used on Indian Railways will be mostly determined by financial considerations except on sections where metal sleepers are likely to be attacked by atmospheric oxidation and on sections where wooden sleepers are likely to be attacked by white ants. As prices stand at present, treated chair with an average life of about 18 years is likely to be the cheapest for use in most of the sections in Northern India. In South India on the East Coast the cast iron pots and plates are likely to be the most economical, whereas in the Western part on the G. I. P. and the B. B. & C. I. lines, steel sleepers are likely to be cheaper. For gauges other than Broad Gauge, metal sleepers will be out of the question for a long time more to come.

Fittings and fastenings (rail and sleeper).

The stresses in the rail fastenings have been raised appreciably by the increase in speeds and loads. They have to resist the forces which tend to pull them out and deform them. The way sleepers stand up depends largely on the tightness of these

fastenings. In addition to holding the rail on to the sleepers, and preserving the gauge, some rail fastenings have also to prevent the creep of the rails. Thus the rail fastenings used on heavy traffic track shall have to be strong, easy to maintain and keep always tight.

Bull-headed rails are mostly laid on wooden sleepers and are attached to the sleepers by C. I. chairs and keys, wooden or spring steel. The cast iron chairs in their turn are attached to the sleepers by means of round spikes or fang bolts.

Flat footed rails are attached to wooden sleepers by means of screw spikes (coach screws) or dog spikes.

Spikes.

The screw spike has a remarkably higher holding power as compared with a dog spike. Tests performed as regards holding power of dog spikes and screw spikes have shown that, whereas the dog spike is pulled out by a pull of $1\frac{1}{2}$ to 2 tons, nearly double the pull is required for pulling out a screw spike. Thus the screw spike considerably increases the life of the sleeper, as it does not require to be often re-driven and even while it has to be re-driven it does not damage the sleeper. But most railways except in England, the Continent and Japan prefer the dog spike for the following reasons:—

1. Takes less time for renewal and makes re-laying easy.
2. Less costly than screw spikes.
3. Holds gauge more firmly than does a screw spike as there is more intimate contact between the shank of the dog spike and the rail.

Bearing plates.

Almost every railway adopts some kind of bearing plate or other on main line track for high speed operation, with wooden sleepers. It prevents the rail cutting into the sleeper and increases the life of the sleeper considerably . It also prevents any movement between the rail and the sleeper and keeps better gauge. Some railways use bearing plates only on curves, especially when using hard wood sleepers. Rail braces on curves may be abandoned when using bearing plates.

Bearing plates must be designed of sufficient area to distribute the load properly on to the sleeper. If it is too thin it bends under the rail foot and produces concentration of loading under the rail foot.

Mild steel bearing plates used on Indian Railways have a section of $10'' \times 10''$ with a minimum thickness of $\frac{1}{2}''$.

The United States use $9'' \times 7\frac{1}{2}''$ bearing plates but for their heavier loads they use $9'' \times 15\frac{1}{2}''$ bearing plates. Japanese Government Railways use $6\frac{1}{4}'' \times 10''$ long bearing plates. Bearing plates in addition to distributing pressure properly on the sleepers prevent lateral movement of rails, whereas sole plates, which are usually only flat in section, do the former function only.

On most railways, where bearing plates are used, they are attached by 2 or 3 spikes to both the rails and the sleepers. Some railways however have separate fittings to connect the bearing plates to the sleepers. This duplication of fittings is not only costly but unnecessary.

Number of spikes.

Most main line railways use 6 spikes to each sleeper on the tangents and 8 spikes to a sleeper on curves and at joints. Using more spikes than are necessary unnecessarily weakens the sleepers.

Fittings for metal sleepers.

Fittings of flat footed rails with metal sleepers usually are keys and cotters. As has already been stated, India is the one country in which the design of metal sleepers has made considerable advance. Clips and bolts have been tried to fit rails on to metal sleepers but this kind of fitting has been found to be unnecessarily costly and unsatisfactory in maintenance. The tapered key is the best fitting for metal sleepers, for, besides providing for a certain amount of adjustment in the gauge, it stops rail creep and holds fast even under very dense traffic.

The Indian Railway standard tapered key is $7\frac{1}{2}''$ long and has a taper of 1 in 32. Prior to this the standard key was $10''$ long and had a taper of 1 in 8 which however was constantly working loose in the track. Generally 4 keys are used for each

sleeper so that the gauge and the alignment can be adjusted to within very fine limits. Recently a key has been designed by the Central Standards Office for Railways in which at the end of the taper the section is again bossed so that once the key is fitted to the rail and the sleeper, it cannot be removed without the prior lifting of the rail.

Anti-creepers (rail anchors).

Most railways use anti-creepers or rail anchors 6 to 16 or even 20 per rail for preventing rail creep. There are more than a score of types of rail anchors patented for the purpose and experiments carried out on Indian Railways, have shown that most of them are quite satisfactory and hence the cost of the rail anchors alone is the main criterion for arriving at a decision regarding the type of rail anchor to be used.

Special rail fastenings.

Many variations of rail fastenings have come into the market all the world over for use on main line tracks with heavy traffic, *e.g.*,

1. Anti-creep bearing plates.
2. Lundie tie plate.
3. Lenz patent dog spikes.
4. Elastic spikes.
5. Spring steel keys.
6. Elastic rail pads.

These have all been tried on various railways with varying degrees of success.

Anti-creep bearing plates.

These are used in connection with wooden sleepers and are fitted with keys for fixing them to the rails instead of dog spikes as in the case of the ordinary bearing plates. They are then attached to the sleepers by means of round spikes or fang bolts. It is advantageous to use these in localities where creep is heavy and requires ordinarily a large number of rail anchors for preventing the creep and bearing plates are to be used for the proper distribution of pressure on the sleepers.

Lundie tie plate.

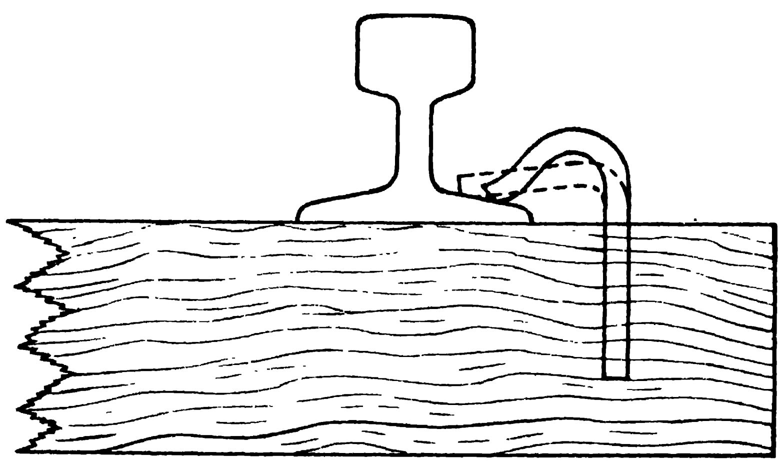
This is a bearing plate in which the top surface instead of being flat is benched and thus increases the friction between the rail and the bearing plate.

Lenz patent dog spikes.

These spikes both round and square in section were tried on the E. B. Railway and were found to be not much superior to ordinary dog spikes.

Elastic spike.

This is made of $\frac{5}{8}'' \times \frac{3}{8}''$ heat treated spring steel double backed on itself. It has a straight shank which is driven into the tie and a goose neck top or head, which extends over, on the rail foot. It is $7\frac{3}{8}''$ long and calls for a special punching of the bearing plate. It is readily driven into a bored hole and easy to attach. The advantages are—it reduces noise, minimises mechanical wear, stiffens the entire track and prevents rail creep and has a very high holding power. It has been tried on the L. M. S. and found to be a success.



ELASTIC DOG SPIKE.

FIG: III

Spring steel keys.

These keys having been made of spring steel increase the grip between the rail and the sleeper and do not get loose.

Elastic rail pads.

Many railways in the United States and on the Continent use soft wood, treated wood, tarred jute, felt, rubber or bakelite rail pads underneath, bearing plates and sole plates for improving the running.

Rail braces.

Japanese Government Railways are the only railways that have tried using these rail braces on curves with a radius smaller than 2,000′. They have now given them up and use instead bearing plates.

C. I. vs. Steel bearing plates.

Both cast iron and steel bearing plates, properly designed, have been found equally efficient in service. Cast iron plates are heavy but cheaper and are not affected by atmospheric conditions. Steel bearing plates are costly and are not ordinarily justifiable except under certain special circumstances. They however make for better running and are easier to fit.

The provision of sleeper and rail fittings depends entirely on the circumstances of the track condition in which they have to be provided. If excessive creep is anticipated, which is with wooden sleepers only, anti-creepers shall have to be provided. It has however been the experience of the N. W. Railway that anti-creep bearing plates are decidedly cheaper when both bearing plates and rail anchors have got to be provided Fittings made of special or spring steels are not economical except under special circumstances when their extra cost can be justified financially. Elastic rubber pads become necessary only for speeds well over 70 miles per hour and as such will not be found necessary for speeds obtaining on Indian Railways.

CHAPTER IV

Formation.

The formation is the natural support to which the various forces set up by passing vehicles are transmitted. It is therefore essential for proper running that it should be able to withstand all this pressure without any subsidence. The increase in the total weight of the vehicles and the axle-loads has in some cases disturbed the formation and caused it to sink progressively on sections where the ground was either unstable or water-logged. The top of the formation on most railways is sloped 2 to 5% from the centre to the outside so as to let all water getting through the ballast drain away more easily. The Dutch Indies State Railways have adopted the practice of ramming in successive layers, the filling forming the railway embankment. Several railways cover the bed, when making it, with an under layer of fine material sand, ashes or clinker 8 to 10 inches thick. This practice increases the life of the ballast as by distributing the pressure more evenly reduces the load on the bed and prevents the ballast being driven into the bed. When the ground is soft or likely to become so when wet, drains can be arranged through this layer of fine material to collect the water and discharge it into ditches specially provided alongside the line. This layer moreover acts as an insulating and absorbent mattress spread over the unstable ground which it covers without penetrating it and preserves it from getting wet.

Some railways tried laying a thin layer of concrete on the formation but this has not been found to be altogether satisfactory. The Alsace Lorraine Railway tried tar-macadam consisting of broken stone, gravel or blast furnace slag coated with tar so as to provide a water proof layer over the formation. Above this they used 20″ ashes and thereon the usual ballast. The French Nord use the layer of tar-macadam without the additional layer of ashes at their Paris terminus where the traffic is very heavy although slow. By its very nature this layer of tar-macadam is flexible enough not to crack or break

and is giving entire satisfaction in either railway referred to above.

The American Railways use perforated concrete or corrugated armco piping in certain localities for providing the necessary internal drainage—a scheme that has been quite successful.

Formation in soft soils.

The following methods may be adopted for dealing with formation in soft soils.

1. Consolidation by ramming.
2. Sloping the surface to provide the necessary gradient for drainage.
3. Filling the top with material like ashes, sand, clinker, slag, etc.
4. Providing cross and longitudinal drains for leading the water coming through the ballast to drains outside the formation.

Solid road-bed.

A solid road-bed of ordinary concrete and reinforced concrete has been found quite useful in certain areas. Where no ballast was used, sleepers were either fixed to this solid road-bed by holding down bolts or let into it in groves provided for the purpose. This solid road-bed is generally used in platforms where the speeds are slow, and is intended to keep the station yards much more sanitary. Solid road-beds have also been used in long tunnels where maintenance is difficult and it is unhealthy for gang-men to remain long. It was, however, found that solid road-beds sank in cases where the soil below was soft and the Japanese Government Railways use them only where the formation is hard.

Studies should be continued to arrive at a design for a proper solid road-bed for use on main line tracks carrying heavy traffic at high speeds that will not sink even into soft soils and be effective in saving maintenance costs.

Ballast.

The ballast is the layer of compact homogeneous material that distributes over the surface of the formation, the pressure due to rolling loads traversing the track. In addition, it ensures by its adhesion to the rails and sleepers the lateral stability of the track, and by its mass in which the sleepers are embedded, it prevents the movement of the sleepers. It has to be permeable so that water can pass through it quickly to the formation whence it is absorbed or carried away by the drainage provided. It has to be easily handled and by its nature to lend itself to the work of restoring and holding the track to the correct level. There is need for a sufficient depth of ballast to distribute the wheel load over a large area of the road-bed surface, and to prevent undue depression of the track. The depth of ballast should be in keeping with the maximum loads and speeds passing over the track. Each railway classifies its track into different classes and specifies different ballast sections for each class. For the sections with the heaviest loads, the greatest depth of ballast sections are specified.

Pressure on ballast.

The formula for finding the pressure on formation obtained by the American Special Committee on stresses in railway track is as follows:

$$p = \frac{16{\cdot}8\, pa}{k^{1\cdot 25}}$$

where p = intensity of vertical pressure at a point k inches below the bottom surface of the sleeper.

pa = mean intensity of pressure at the bottom surface of a sleeper.

The Japanese Government Railways adopt the formulae

$$po = \frac{kK^2}{\pi}\int_{-a}^{2l-a} p.x.e^{-k^2x^2}\,dx$$

where $K = \frac{1}{0{\cdot}7\,h + 2{\cdot}3}$ (h in c.m.)

& k = depth from bottom of sleeper.

Nature of ballast.

Broken stone and slag are better than any other materials. They are heavy, angular. Non-absorptive. They give good drainage, prevent weed growing and resist crushing. They are not friable, nor are they subject to cleavage by frost. Some railways, where broken stone is rather costly, use it only for main lines and use screened ballast for other lines. In India broken granite or hard trap is used for main lines. Railways, on which the line is levelled by shovel packing, use either screened small ballast specially supplied for the purpose or a small top layer of ballast or gravel.

Size of ballast.

The size used generally varies from 13/16″ to 2-$\frac{3}{4}$″. On Indian Railways 1″ ballast is used for points and crossings, 1-$\frac{1}{2}$″ for metal sleepers and 2″ for wooden sleepers.

The Belgian National Railways used 1-9/16″, to 2-3/8″ on main lines and 3/8″ to 2″ on secondary lines. Some railways use large sizes such as 2-3/8″ to 3-1/8″ and are averse to mixing the smaller sizes with them. Some railways, such as the French Nord, use on an extensive scale a top layer of fine ballast for final levelling of the track and for making up purposes. English railways even to-day put down an under-layer of big sized ballast 3″ to 8″ in diameter and on the top of it place the ordinary ballast. They further use fine ballast $\frac{1}{4}$″ in size for packing under sleepers.

Too big a ballast makes packing and levelling difficult.

Depth of ballast.

The general tendency is to increase the depth of ballast underneath the sleepers. 20″ of ballast is considered to give a good unyielding track. From the formulae quoted previously it may be seen that even with a 10″ depth of ballast the pressure on the formation is reduced to 33 to 50 per cent of what it is at the under-side of the sleeper.

On Indian Railways the average depth of ballast used is 8″ to 10″. On many railways existing ballast is retained as a stable and resistant under-layer between the bed and the

newly added layer of ballast on the track. When putting down new lines or carrying out complete renewals certain railways such as the Reichsbahn and the Austrian Federal Railways ram or roll the ballast before putting the permanent way in position.

Testing of Ballast.

Most railways do not test ballast before purchase but specify the nature, source, size, weight, etc. Indian Railways usually gauge the ballast before paying for it.

On some railways the following shock test is made:

A sample 80 lbs. in weight is taken and all stones passing through a screen of 1-9/16" are eliminated. This should not be more than 12%. Each test as described below comprising of three operations is performed on 8 to 10 lbs. of ballast.

The dry ballast is placed in a cast steel container nearly 7" diameter and 6" high. It is given 20 blows from a tup weighing 110 lbs. at the rate of 2 blows a minute falling from a distance of 13". After each blow the vessel containing the ballast is revolved 1/8" of a turn on its vertical axis.

After the above treatment with the tup the ballast is emptied into a screen with 6 frames and diaphragms fitted as under:

220 holes of 1" diameter; 600 holes of 19/32" dia.; holes of 9/32" dia.; $\frac{1}{8}$" square holes; 3/64" square holes; unperforated plate.

The percentage of the quantities gathered in each sieve is determined and multiplied in order by the following depreciation co-efficient;

0; 0·4; 0·8; 1·2; 1·6; and 2·0.

The sum of these products which represents the percentage of depreciation should be less than 0·30.

Quantity of ballast.

The resistance of ballast against the lateral displacement of sleepers is effected by the width of ballast outside the ends of the sleepers. It increases to some extent according to the width, but attains a maximum value for a width of 15-$\frac{3}{4}$" to 17-$\frac{11}{16}$"; a further increase in width is by no means useful. The resistance of track against lateral displacement is quite effective in maintaining the alignment of the track against the blows of

high speed trains, and preventing deformation due to a sudden temperature rise. Therefore it is desirable to make the ballast outside the end of the sleepers over 15″.

Ballasting up to upper surface of the sleepers increases the stability of the track. In fact this is usually done on most railways except in the United States where the upper part of the sleepers is exposed to ½″ to 2″. In this connection it should however be borne in mind that the sleepers in the United States are much thicker than elsewhere. Some railways use ballast nearly to the top of the rails, but this extra quantity does not serve much useful purpose, and makes inspection of sleepers difficult.

Japanese experiments on ballast.

The Japanese Government Railways have carried out experiments with several kinds of ballast and investigated the time required for maintenance work. It has been found that the labour required for track with broken stone is only 52—72% of that with screened ballast, and even in the case where broken stone is used only at the rail joint, the maintenance work is decreased by nearly 19%.

The resistance of broken stone against track displacement is larger than that of gravel. It has been found by investigations that the amount of creep in the case of track with broken stone ballast is less than with gravel ballast by about 20 per cent.

Layout.

The increase in the loads and speeds of trains has necessitated the layout of a track with easier gradients and flatter curves. Many delicate problems are raised in running over curves and the solutions depend on the knowledge and experience of permanent-way engineers. The longer engines, and carriages designed at the present day make it difficult for them to negotiate sharp curves, *e.g.* the greatest rigid wheel base that can negotiate a 400′ curve is 32′-2″ and even this cannot be done at speeds beyond 56 m.p.h. Some of the big steam locomotives of the present day design cannot negotiate curves sharper than with a radius of 800′. Really high speeds are possible only with curves which do not require gauge slackening or widening for the amplitude of hunting increases with disastrous effects on both the rolling stock as well as the track.

On Indian Railways $1\frac{1}{2}^{\circ}$ curves provided with transition and 1° curves without transition are considered to be the maximum degrees of curvature for running trains at unrestricted speeds.

Gauge on curves.

The widening of the gauge on curves has been under consideration for a long time now. On Indian Railways, it has been decided that no widening should be done for curves up to 4° of curvature, and it is not expected that on the heavy traffic main lines any curves sharper than this would be used. On some railways 13/16" is considered to be the maximum limit up to which the gauge may be widened, but this appears to be rather a dangerously large maximum. For modern speeds no curve should be widened by more than a $\frac{1}{4}$ of an inch.

Maximum degree of curvature.

Many railways have fixed 1° as the maximum degree of curvature permissible on main lines. This maximum is arrived at with reference to the maximum cant that can be given to the outer rail for speeds approaching 80 to 90 m.p.h. without actually interfering with the stability of the vehicles when stationary.

Maximum amount of cant given to the outer rail.

The amount of cant that is usually given to the outer rail depends on the degree of curvature as well as the speed. On many railways the amount of cant is given for the weighted average speed of all the trains running on it. The cant given on many railways is limited to a maximum of 4" to 6", so that the stability of stationary vehicles may not be seriously impaired. A rule followed by many railways for fixing the maximum cant is 1/12 of the gauge.

Easing of super-elevation.

The cant given to a curve is usually eased of at the rate of 1 inch in 40 feet to a hundred feet on the straight, where curves are provided with transitions; this easing is usually done in the transitions. No cant however is given to curves in turnouts.

Transition curves.

All curves on main line tracks are provided now with suitable transition curves. Some railways however do not provide transition curves for curves flatter than with a radius of 3,000′. Such railways however do not contemplate running speeds in excess of 50 miles per hour. The transition curves used by most railways is the cubical parabola, or the semi-cubical parabola which are the two nearest approaches to an involute.

$$Y = \frac{x^3}{n. L. R}$$

The Egyptian Railways use the hyperbola, while the Dutch Indies State Railways make use of the parabola of the 5th degree.

When the question is one of transitions between reverse the tendency is to consider the two curves as independent, and curves provide each with a separate transition separated by a piece of tangent or straight track of not less than 100 to 200 feet in between. Of course, reverse curves are to be avoided as much as possible.

Maximum speed on curves.

Although the question of speed on curves has been discussed at great length, no finality has so far been reached on the subject. One of the factors that limits the speed on curves is the maximum cant that can be given to the outer rail.

Based on various experiments made on Italian Railways, they have arrived at the following formulae for speed on curves.

$$V = 2{\cdot}8 \sqrt{R} \qquad \text{for zero cant.}$$

$$V = 4{\cdot}5 \sqrt{R} \qquad \text{for a cant of 150 m.m.}$$

where V is kilometers per hour and R is the radius of the curve in meters.

On Indian Railways the maximum speed permitted depends on the gauge, the super-elevation given and the fact whether a transition is or is not provided.

For the broad gauge the permissible speed on curve is given by the formulae

$$V \quad 1{\cdot}5 \sqrt{R-220}$$

where V is the speed in miles per hour and R the radius of the curve in feet.

For untransitioned curves 4/5 of the above speed is to be taken. Super-elevation is limited to $5\frac{1}{2}''$.

Lubrication of the outer rail.

Mention may be made of specially hardened rails used by some railways on curves as well as of the lubrication of the inner face of the head of the outer rail adopted by others to reduce wear of the outer rail. These methods have been found to be effective in reducing rail wear especially where the cant has been provided for the weighted average speed and not the maximum speed at which trains are scheduled to run. The cost and maintenance of fitting the apparatus for providing this lubrication has been found to be negligible in comparison with the saving in rail wear to be had therefrom.

CHAPTER V

Turnouts.

High overall speeds become possible only when they can be maintained over long lengths without having to slow down at stations because of restrictions imposed for through running over points and crossings. Generally speaking, there is no particular difficulty in running through points when set for the through track. No railway has any restriction for trailing points but some railways have a speed restriction for facing points even though the through track is intended to be used, for considerations of signalling and safety although not on account of the question of comfort or stability of the vehicle.

The postition is quite different when the vehicle has to run into a branch line. Indian Railways have a speed restriction of 10 miles per hour on non-interlocked points and 20 miles per hour for mechanically interlocked points for running over the turnout into the branch line. Almost every railway has a speed restriction imposed for taking the branch line, which varies from 10 to 50 miles an hour. Some of the American Railways limit it to 2 to 2·5 times the co-tangent of the angle of the crossing. On the Japanese Railways the speed is limited to 2/3 of the speed permitted on curve of the same radius as the turn-out because of the lack of provision of proper super-elevation and widening of the gauge. In order to get over this difficulty many railways have used crossings with co-tangent numbers as high as 20 to 25. 16 is considered the minimum. The Swedish Railways use as small an angle as 25′ for the fitting of the tongue rails. It should be noted that while this long tongue rail facilitates the straight running, it reduces the radius of curvature for the branch line running.

Some railways super-elevate the turnout, easing it both at the points and the crossing. Similarly, some railways widen the gauge which is again brought to exact gauge both at the nose of the crossing and the switch. But most railways neither super-elevate nor widen the gauge. Some railways lay the switch

rails and the crossing vertical without the usual 1 in 20 cant for providing for the conicity of the wheel tyres.

The standard turnouts on Indian Railways are 1 in $8\frac{1}{2}$ and 1 in 12. No special high speed turnouts have been designed although in the case of the 1 in 12 turnouts 21 feet switch rails are used. Indian Railway standard turnouts are the same for both the straight and the curved track.

Points.

The modern tendency is to increase the length of the switch rail so that fast trains can travel easily on the straight track. On most railways the flat footed rail is machined from about the middle of the switch rail to form the blade. This blade is not symmetrical and has a very thin web and as such is not usually stable and cannot take any load until its head is at least one inch wide. Indian Railways use over-riding switches in which the switches are $\frac{1}{4}''$ above the stock rail and take the entire load of the wheel. This has saved the replacement of a considerable number of stock rails. The Japanese Government has a special section of rail for the manufacture of the switch blades. Some railways have used a very much harder rail for the switches but this has not been found a great economy. Some other railways have used high carbon-treated switch points welded to the switch rails. It is too early to proclaim the success of these high carbon switch points. Some railways have tried switch protectors which deflect the flange and prevent it from striking the end of the point. In many cases these switch point protectors have prolonged the life of the point.

Crossings.

Crossings are generally built up from ordinary rails but some railways use mono-block manganese steel crossings. These have no fittings to tighten and stand up very well under wear. Some railways use only the V piece of mono-block steel and make up the rest of the crossing from ordinary rails. The use of mono-block steel crossings is recommended for lines carrying heavy traffic at high speeds. The length of the crossing itself has assumed considerable importance of late and varies from 10′ to 30′ nearly. The wing rail is raised so that the wheel may not come down sudden upon the nose of the crossing, especially because the crossing is laid flat.

Japanese Railways use movable crossings which maintain the continuity of the track without any break. The only disadvantage of movable crossings is the extra provision for signalling necessary as well as the connection required between the switch and the crossing.

Some railways have tried spring crossings which are ordinarily set for the main line and have to be opened out by the flange of the wheel tyre when a train has to pass to or from the branch line. These are very economical in localities where the bulk of the traffic passes along the straight track.

Japanese Railways use special crossings for slip and other similar sidings for which the traffic is very seldom set.

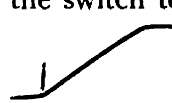
Many railways use harder steel for crossings.

Here is the specification of nickel manganese steel used on American Railways for crossings.

Carbon	..	0·6 to 0·9	per cent.
Manganese	..	11·0 to 13·5	„
Nickel	..	2·5 to 3·5	„
Silicon	..	·6 to ·85	„
Sulphur & Phosphorus		·04% max.	

Physical properties.

60—70 tons tensile strength with 25 tons yield point. Elongation on a 2″ gauge length is 55 per cent. This hard metal can be easily welded to ordinary built up low carbon crossings.

Many railways have considered the linking of switch blades and the crossings so that creep may not affect them. On some railways, an angle bar is attached to the under-side of the sleepers so that the sleepers do not move their position. On Indian Railways, a switch anchor is used fixing the switch to the stock rail. It is a piece of steel shaped thus  and connects the switch and stock rails behind the heel.

Railways in India and a few on the Continent use steel sleepers for crossings. These steel sleepers are cheaper in the long run and get themselves firmly embedded on the track and make maintenance of crossings easy.

The L. N. E. R. have tried some crossings made of chrome steel which have been found to be fairly satisfactory in service.

Some railways have used rail braces for absorbing lateral shocks at the check rails near crossings.

Guard rails for crossings.

Wheels must be led at crossings by guard rails a sufficient distance to prevent the violent lateral blow that usually occurs at crossings and to avoid the risk of running into the wrong line. The length of the guard rail must be determined in accordance with the rolling stock to be operated on the section, for, if they are too long, they will be struck several times by the back surface of the inner wheel when a locomotive with a long rigid wheel base passes over the switch and the wheel is apt to over-ride the rail owing to friction set up by such contacts.

Many railways use guard rails shorter than 16′ but some like the Delawar and Hudson Railroad use 20′ guard rails.

Guard rails for level crossings and curves.

With steel sleepers where there is no provision for the check or guard rails to be fitted in, specially designed sections

as these are attached to the running rails by means

of bolts. They certainly are not as efficient as ordinary guard rails but still to a large extent serve the purpose. Most railways provide guard rails on curves sharper than 5°.

CHAPTER VI

CONSTRUCTION OF MODERN TRACK.

The tendency in the methods adopted for the construction of modern track is increased mechanization which ensures speedy construction as well as better workmanship and is ultimately economical when long lengths have to be constructed.

Amongst modern track recently constructed, mention may be made of the following two examples :—

1. Norfolk Western Railway.

   145 men laid 37·3 track miles including 55 turn-outs in 19½ working days.

2. New rail link to the Gulf completed with extensive use of mechanised construction. 110 miles completed in one year.

Mechanical appliances for track construction.

The mechanical appliances used for modern track construction are many, *e.g.*:—

1. Power shovels for earth work.
2. Tie boring machines.
3. Power drills for drilling rails.
4. Power adzing machine for sleepers.
5. Power wrenches for tightening bolts and nuts.
6. Track surfacing machines, etc.

In the latter construction referred to above, fittings, etc., were distributed by automobile cars running along the formation which resulted in quite a lot of saving in time.

Collet system of track construction.

The Collet system of track laying used in Switzerland deserves special mention. Lengths of track are assembled at a convenient depot, run out to the site and dropped on to the prepared road-bed from gantries mounted on Diplory bogies running on temporary tracks. This system is quite economical and speedy for complete relaying of the track.

CHAPTER VII

MODERNISING EXISTING TRACK FOR INCREASED LOADS AND SPEEDS.

Generally speaking, many of the existing tracks have been constructed for light loads moving at slow speeds, with steep gradients and sharp curves, and as such cannot take modern heavy loads at high speeds.

In order to operate heavy loads at such high speeds, the following points should be taken into consideration to ensure safe operation of trains.

1. Safety of trains against derailment and overturning.
2. Strength of the track to bear the impact caused by high speed operation of heavy loads.
3. Strength sufficient to maintain the track in perfect condition.

Steps to be taken to modernise existing track depend on the condition and nature of the existing track and the extent to which it is to be modernised to meet the loads and speeds coming on it. As in many instances the increase in the speed and the loads has been gradual; in such cases the progress of modernisation also has been gradual.

Modernisation of the track in most instances has consisted of one or more of the following :—

(a) Replacing, where necessary, short and light rails with heavier and longer ones.

(b) Welding rails to form long rails.

(c) Increasing the number of sleepers.

(d) Provision of bearing plates where none existed previously.

(e) Improvements in—

 (i) rail joints, and

 (ii) rail and sleeper fastenings.

(f) Increase in the quantity and quality of the ballast.

(g) Breaking existing ballast into the proper size.

(h) Providing proper drainage to ensure effective drainage of water in defective formations.

(i) Providing proper super-elevation to the curves.

(j) Providing proper transitions where none existed before.

(k) Increasing the lengths of existing transitions : many railways use transition as long as 1,000 to 15,000 times the super-elevation.

(l) Realignment of curves.

(m) Regrading of the section where necessary.

(n) Providing longer and stronger switch rails.

(o) Repairing crossings by welding.

(p) Lubrication of tracks at curves and other places of exceptional wear.

(q) Provision of sufficient number of rail anchors for preventing rail creep.

(r) Provision of rail braces for curves and crossings.

(s) Hardening of rail ends.

(t) Regauging.

(u) Making old material serviceable by welding.

CHAPTER VIII

ECONOMICAL ASPECT OF MODERN TRACK.

The modernising of permanent way is more an economic than a technical problem. No expenditure on track equipment may be incurred unless the average annual savings that could be realised from such expenditure are sufficient to meet the annual cost of service of such equipment. This latter comprises of the following items :—

1. Annual interest on the capital outlay incurred.
2. Annual maintenance, and repair costs.
3. An annual payment to be made to a sinking fund (real or imaginary) so that at the end of the life of the equipment, there will accrue in the sinking fund enough money which together with the compound interest thereon will provide the amount required for the replacement of the equipment.

Two factors that constitute sound track engineering are economic design and economic selection, and when the final choice to be made is dependent on the cost of the equipment, the principles of economic design have to be co-ordinated with principles of economic selection.

The main principle of economic selection is *least cost in the long run.* Thus, for selecting one of two different types of equipment capable of rendering the required service, the annual cost of service or cost per unit of service of each type is ascertained and the equipment with the lower annual cost or unit cost should be selected.

$$\text{Cost per unit of service} = \frac{\text{Annual cost of service}}{\text{No. of units of service rendered annually.}}$$

The principle stated above is illustrated by the following examples.

Example I

Suppose the choice to be made is between Wooden and Steel sleepers.

Data for computing yearly costs.

Particulars.	*Wooden sleepers.*	*Steel sleepers.*
Cost per sleeper.	Rs. 4/-	Rs. 7/-
Cost of fittings.	Re. 1/-	Re. 1/-
Average life.	12 years.	37½ years.
No. required per mile.	2,200	2,200
Scrap value of sleepers.	0/4/0	1/4/0 each including fittings.
Secondhand value of fittings.	0-12-0	
Yearly cost of maintenance and upkeep etc., per mile	Rs. 333/-	Rs. 333/-
Cost of transportation of sleepers to site per mile.	Rs. 500/-	Rs. 1,000/-
Cost of laying per mile length of track.	Rs. 1,100/-	Rs. 1,650/-
Outstanding data.	Nil.	

Yearly cost of service.

(*a*) *Wooden sleepers.*

Cost of maintenance and upkeep etc.	..	Rs. 333/-
Interest on capital (rate of interest 6% per annum)	..	Rs. 756/-

Capital cost for computing interest.

Cost of 2,200 sleepers and fittings Rs. (4 + 1) each	=	Rs. 11,000
Cost of laying	=	Rs. 1,100
Cost of transportation	=	Rs. 500
Total	..	Rs. 12,600

Sinking fund payment shall be made on Rs. (12600 less Rs. 2200 scrap value) = Rs. 10400.

From Table I, the figure corresponding to 12 and 6% is ·0593 which multiplied by 10,400 gives Rs. 617 .. Rs. 617

Total annual cost .. Rs. 1,706

(*b*) *Steel sleepers.*

Cost of maintenance and upkeep	..	Rs. 333/-
Interest on capital cost	..	Rs. 1,215/-

Capital cost

2,200 sleepers at Rs. (7 + 1) each	=	17,600
Cost of laying	=	1,650
Cost of transportation	=	1,000
	=	20,250

Rate of interest = 6%

Sinking fund payment shall be made on Rs. (20250—2200 scrap value) = Rs. 18,050

From Table I, the figure against 37 and 6% is ·0079 and against 38 and 6% is ·0074

∴ The mean for $37\frac{1}{2}$ years is ·00765.

This multiplied by 18050 gives 138 .. Rs. 138/-

Total annual cost .. Rs. 1,686

Comparing the yearly costs steel sleepers are cheaper by Rs. 20/- per mile and therefore the choice should be in their favour.

Example II

The problem for consideration is as follows :—

A line fitted with 85 lbs. B.H. rails has to be either fitted with 2 additional sleepers, one duplex joint sleeper and new fish plates and bolts, or replaced with 90 lbs. F.F. rails, in order that heavier engines may be run.

Data for computing cost of service.

For equipping additional track fittings.		Fitting New 90 lbs. rail.	
Cost of two additional sleepers including fittings	.. Rs. 10	Cost of 2 new 90 lb. rails including carriage and laying	.. Rs. 100
Cost of duplex joint sleeper including fittings	.. Rs. 20	Life ..	.. 60 years
Cost of fish bolts and plates	.. Rs. 4	Rate of interest	.. 6%
Cost of fitting these in each	.. Rs. 2	Scrap value	.. Rs. 42
Further life of 85 lbs. rail	.. 30 years		
Scrap value of 2 rails 36′ long	.. Rs. 40		
Scrap vlaue of fittings	.. Rs. 4		
Secondhand cost of two 85 lb. rails 36′ long	.. Rs. 60		
Rate of interest	.. 6%		

Maintenance and repair cost are considered to be the same in both cases.

Outstanding data :—

(1) Steel scrap has a very high price in the market and new rails can be had cheap under an old contract.

(2) The old rails cannot be used elsewhere.

Annual cost of service.

For fitting additional fittings.

Interest on :—

2 sleepers	10	
Duplex joint sleepers new ..	20	
Cost of fish plates and bolts ..	4	
Cost of fitting	2	
Secondhand value of old rail ..	60	Rs. 5·64
	96	
Less scrap value of fish plates and bolts	2	
Total ..	94	

Sinking fund payment
(Table I, 30 years, 6% = ·0126)

Amount of sinking fund on
Rs. (10+20+4+2+60—40+40)
i.e., Rs. 52 .. .. Rs. ·65

Total annual cost Rs. 6·29

For new rails.

Interest on :—

Cost of new rails and fittings, etc.,	Rs. 100	Rs. 7·08
+ secondhand cost of old rails	+ 60	
less scrap value of old rails and fish plates, etc.	— 42	
Total ..	Rs. 118	

Sinking fund payment
(Table I, 60 years 6% ·0019)

Amount of sinking fund
= (100—42)
= 58 .. .. .. Rs. ·12

Total annual cost .. Rs. 7·2

It is therefore cheaper to provide 2 extra sleepers, 1 Duplex joint sleeper and new fish plates and bolts.

From the outstanding data it may be seen that were it possible to use the B.H. rails elsewhere on the line, it would be cheaper to provide new rails instead of these additional fittings. SINKING FUND PAYMENT TABLE (See overleaf)

The use of the Table.

Example :—What sum must be paid at the end of each year to the Sinking Fund so that interest at 4 % compounded annually together with the annual payments shall at the end of 18 years amount to Rs. 2,000.

Opposite 18 under 4% we find 0·0309 which is the annual payment required for Re. 1/- so, for Rs. 2,000, the annual payment is 2000 × 0·0309, *i.e.*, Rs. 61·8.

TABLE I

SINKING FUND PAYMENT TABLE.

n = normal life of assets in years.

n	2%	2½%	3%	3½%	4%	4½%	5%	6%	7%	8%
1	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
2	0·4950	0·4938	0·4926	0·4914	0·4902	0·4890	0·4878	0·4854	0·4831	0·4808
3	0·3268	0·3251	0·3235	0·3219	0·3203	0·3188	0·3172	0·3141	0·3111	0·3080
4	0·2426	0·2408	0·2390	0·2373	0·2355	0·2337	0·2320	0·2286	0·2252	0·2219
5	0·1922	0·1902	0·1884	0·1865	0·1846	0·1828	0·1810	0·1774	0·1739	0·1705
6	0·1585	0·1565	0·1546	0·1527	0·1508	0·1489	0·1470	0·1434	0·1398	0·1363
7	0·1345	0·1325	0·1305	0·1285	0·1266	0·1247	0·1228	0·1191	0·1156	0·1121
8	0·1165	0·1145	0·1125	0·1105	0·1085	0·1066	0·1047	0·1010	0·0975	0·0940
9	0·1025	0·1005	0·0984	0·0964	0·0945	0·0926	0·0907	0·0870	0·0835	0·0801
10	0·0913	0·0893	0·0872	0·0852	0·0833	0·0814	0·0795	0·0759	0·0724	0·0690
11	0·0822	0·0801	0·0781	0·0761	0·0741	0·0722	0·0704	0·0668	0·0634	0·0601
12	0·0746	0·0725	0·0705	0·0685	0·0666	0·0647	0·0628	0·0593	0·0559	0·0527
13	0·0681	0·0660	0·0640	0·0621	0·0601	0·0583	0·0565	0·0530	0·0497	0·0465
14	0·0626	0·0605	0·0585	0·0566	0·0547	0·0528	0·0510	0·0476	0·0443	0·0413
15	0·0578	0·0558	0·0538	0·0518	0·0499	0·0481	0·0463	0·0430	0·0398	0·0368
16	0·0537	0·0516	0·0496	0·0477	0·0458	0·0440	0·0423	0·0390	0·0359	0·0330
17	0·0500	0·0479	0·0460	0·0440	0·0422	0·0404	0·0387	0·0354	0·0324	0·0296
18	0·0467	0·0447	0·0427	0·0408	0·0390	0·0372	0·0355	0·0324	0·0294	0·0267
19	0·0438	0·0418	0·0398	0·0379	0·0361	0·0344	0·0327	0·0296	0·0268	0·0241
20	0·0412	0·0391	0·0372	0·0354	0·0336	0·0319	0·0302	0·0272	0·0244	0·0219
21	0·0388	0·0368	0·0349	0·0330	0·0313	0·0296	0·0280	0·0250	0·0223	0·0198
22	0·0366	0·0346	0·0327	0·0309	0·0292	0·0275	0·0260	0·0230	0·0204	0·0180
23	0·0347	0·0327	0·0308	0·0290	0·0273	0·0257	0·0241	0·0213	0·0187	0·0164
24	0·0329	0·0309	0·0290	0·0273	0·0256	0·0240	0·0225	0·0197	0·0172	0·0150
25	0·0312	0·0293	0·0274	0·0257	0·0240	0·0224	0·0210	0·0182	0·0158	0·0137
26	0·0297	0·0278	0·0259	0·0242	0·0226	0·0210	0·0196	0·0169	0·0146	0·0125
27	0·0283	0·0264	0·0246	0·0229	0·0212	0·0197	0·0183	0·0157	0·0134	0·0114
28	0·0270	0·0251	0·0233	0·0216	0·0200	0·0185	0·0171	0·0146	0·0124	0·0105
29	0·0258	0·0239	0·0221	0·0204	0·0189	0·0174	0·0160	0·0136	0·0114	0·0096
30	0·0246	0·0228	0·0210	0·0194	0·0178	0·0164	0·0151	0·0126	0·0106	0·0088
31	0·0236	0·0217	0·0200	1·0184	1·0169	0·0154	0·0141	0·0118	0·0098	0·0081
32	0·0226	0·0208	0·0190	0·0174	0·0159	0·0146	0·0133	0·0110	0·0091	0·0075
33	0·0217	0·0199	0·0182	0·0166	0·0151	0·0137	0·0125	0·0103	0·0084	0·0069
34	0·0208	0·0190	0·0173	0·0158	0·0143	0·0130	0·0118	0·0096	0·0078	0·0063
35	0·0200	0·0182	0·0165	0·0150	0·0136	0·0123	0·0111	0·0090	0·0072	0·0058
36	0·0192	0·0175	0·0158	0·0143	0·0129	0·0116	0·0104	0·0084	0·0067	0·0053
37	0·0185	0·0167	0·0151	0·0136	0·0122	0·0110	0·0098	0·0079	0·0062	0·0049
38	0·0178	0·0161	0·0145	0·0130	0·0116	0·0104	0·0093	0·0074	0·0058	0·0045
39	0·0172	0·0154	0·0138	0·0124	0·0111	0·0099	0·0088	0·0069	0·0054	0·0042
40	0·0166	0·0148	0·0133	0·0118	0·0105	0·0093	0·0083	0·0065	0·0050	0·0039
41	0·0160	0·0143	0·0127	0·0113	0·0100	0·0089	0·0078	0·0061	0·0047	0·0036
42	0·0154	0·0137	0·0122	0·0108	0·0095	0·0084	0·0074	0·0057	0·0043	0·0033
43	0·0149	0·0132	0·0117	0·0103	0·0091	0·0080	0·0070	0·0053	0·0040	0·0030
44	0·0144	0·0127	0·0112	0·0099	0·0087	0·0076	0·0066	0·0050	0·0038	0·0028
45	0·0139	0·0123	0·0108	0·0095	0·0083	0·0072	0·0063	0·0047	0·0035	0·0026
46	0·0135	0·0118	0·0104	0·0091	0·0079	0·0068	0·0059	0·0044	0·0033	0·0024
47	0·0130	0·0114	0·0100	0·0087	0·0075	0·0065	0·0056	0·0041	0·0030	0·0022
48	0·0126	0·0110	0·0096	0·0083	0·0072	0·0062	0·0053	0·0039	0·0028	0·0020
49	0·0122	0·0106	0·0092	0·0080	0·0069	0·0059	0·0050	0·0037	0·0026	0·0019
50	0·0118	0·0103	0·0089	0·0076	0·0066	0·0056	0·0048	0·0034	0·0025	0·0017
55	0·0101	0·0087	0·0073	0·0062	0·0052	0·0044	0·0037	0·0025	0·0017	0·0012
60	0·0088	0·0074	0·0061	0·0051	0·0042	0·0035	0·0028	0·0019	0·0012	0·0008
65	0·0076	0·0063	0·0051	0·0042	0·0034	0·0027	0·0022	0·0014	0·0009	0·0005
70	0·0067	0·0054	0·0043	0·0035	0·0027	0·0022	0·0017	0·0010	0·0006	0·0004
75	0·0059	0·0047	0·0037	0·0029	0·0022	0·0017	0·0013	0·0008	0·0004	0·0002
80	0·0052	0·0040	0·0031	0·0024	0.0018	0·0014	0·0010	0·0006	0·0003	0·0002
85	0·0046	0·0035	0·0026	0·0020	0·0015	0·0011	0·0008	0·0004	0·0002	0·0001
90	0·0040	0·0030	0·0023	0·0017	0·0012	0·0009	0·0006	0·0003	0·0002	0·0001
95	0·0036	0·0026	0·0019	0·0014	0·0010	0·0007	0·0005	0·0002	0·0001	0·0000
100	0·0032	0·0023	0·0016	0·0012	0·0008	0·0006	0·0004	0·0002	0·0001	0·0000

BONDED BRICK CONCRETE ROADS, PLAIN & REINFORCED

By

A. K. DATTA, Member.

One of the latest developments in the domain of cement concrete roads in India is the Bonded Brick Concrete Road, Plain and Reinforced. Bonded Brick Concrete Roads.

Bricks :—Of all road-making materials bricks are supposed to be the cheapest in India. These are available in most places in India at cheap rates and are commonly used as soling under the road bed. Bricks as a surfacing material are sometimes used in places subjected to light traffic, unless hard compressed and vitrified bricks are used as a surfacing material to withstand heavy wear and tear in roads. Bricks as road-making materials cheapest.

Cement concrete :—Cement concrete as a road-making material has stood the test of time and of heavy traffic. Of all road-making materials it is supposed to be one of the best. It provides in one, a strong foundation with a hard wearing surface. In the word of Mr. Henry Ford of Motor Car fame "a properly constructed concrete road surface will outwear anything else known". Concrete roads are making headway in many countries of the world. Good concrete roads are very strong and require very little maintenance cost ; the surface is smooth, not undulating like ordinary asphalt roads, not slippery, and is ideal for rapid drives.

The main drawback of the cement concrete roads in India is its initial high cost. It is for that reason that concrete roads are not making a good headway in India. The total mileage of cement concrete roads in India may not be more than 200 miles though there are more than 65,000 miles of pucca (metalled) roads and more than 100,000 miles of *kutcha* (unmetalled) roads in India. Drawback of concrete roads—high initial cost.

The main object of the bonded brick concrete construction is to minimize the initial cost of the concrete roads. The cost of cement concrete in India is between Rs. 60/- to Rs. 100/- per 100 c.ft.

ative cost of ks and crete.

The cost of 100 cft. of bricks is between Rs. 10/- and Rs. 20/-. Roughly the cost of bricks is about 1/5th to 1/6th of the cost of common concrete. So in a cement concrete road if bricks replace a major part of the concrete in the lower part, leaving some concrete on the top to take up the wear and tear, and some concrete in the joints between the bricks to make bonding between the upper and lower parts, the concrete and the bricks will work together as one mass of the full depth without any chance of separation between them. This is called bonded brick concrete. Figure 1 shows a section of all concrete and Figure 2 shows a section of Bonded Brick Concrete. Fig. 3 shows a plan of the same on A. B.

Fig. 1

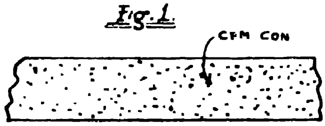


Fig. 2

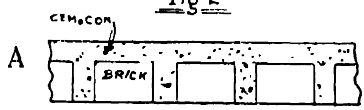
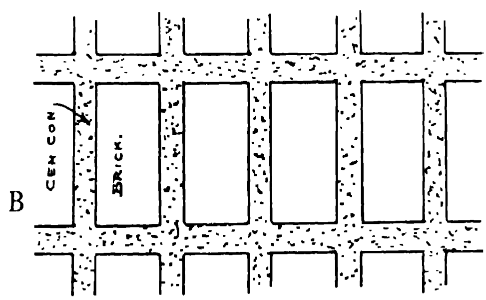


Fig. 3



Figs. 2 & 3 clearly show that bricks are surrounded by concrete on all four sides and on the top and as such there cannot be any separation between them.

1. BONDED BRICK CONCRETE ROADS. (B. B. C.)

B. C.

Bonded Brick Concrete with the cement concrete surfacing produces sound and economical roads where the lower part is of bricks with which the surface concrete is interbonded by extending ribs of concrete into the joints between the bricks.

A thin concrete facing, say 1″ to 2″ thick, when laid on ordinary water-bound macadam roads, usually cracks and breaks up under heavy traffic, but when the same thin layer of concrete is interbonded with a layer of bricks down below, thereby increasing the combined depth to that of the concrete plus bricks, the combined thing stands the traffic quite satisfactorily. Bricks, concrete at the joints and the top concrete all work together as one mass of the full depth. The upper concrete surfacing is never separated from the lower brickwork

as the concrete keys prevent the separation between the two. This is called Bonded Brick Concrete Road as bricks and concrete are interbonded together.

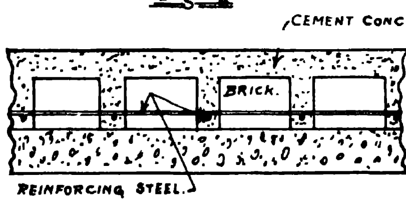
2. REINFORCED BRICK CONCRETE (R. B. C.)

R. B. C.

The bonded brick concrete as specified above can be used either plain without steel reinforcements or with steel reinforcements. The reinforcements are generally used at the bottom. In some cases they are used at the top and in some cases both at the bottom and the top, according to circumstances.

Fig. 4 is an illustration of a R.B.C. Road.

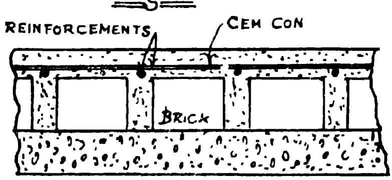
Fig. 4



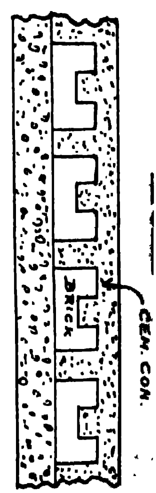
B. B. C. & R. B. C. with common bricks.

In Fig. 4 the reinforcements were used at the bottom only. Fig. 5 shows a section of a road with reinforcements at the top.

Fig. 5.



B. B. C. & R. B. C. with bonding bricks.

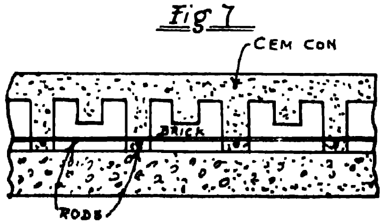


3. Further investigations showed that the bonding between the upper concrete and the lower bricks is increased by the use of bricks with cavities such as 10″×5″×4″ with two cavities 2″×2″×2″. Figure 6 shows a section of a B.B.C. Road with bonding bricks.

These can be used also with reinforcements for increasing their strength.

Figure 7 shows a section :—

Fig. 7



4. R.B.C. & B.B.C. ROADS WITH STONE BRICKS AND BOULDERS.

B. B. C. & R. B. C. with stone bricks and boulders.

In many hilly places burnt bricks are not easily available or they are very costly, but stone bricks and boulders are available in plenty and are very cheap. In such cases burnt bricks are supplanted by stone bricks and boulders. Figure 8 shows a section of a bonded stone brick concrete road and figures 9 and 10 show sections of reinforced stone brick concrete roads, with or without concrete on the top. In places where stone bricks are very hard and the surface dressed well, no extra concrete is necessary on the top of the stone bricks.

Fig 8.

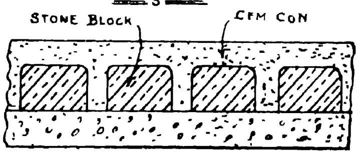


Fig. 9.

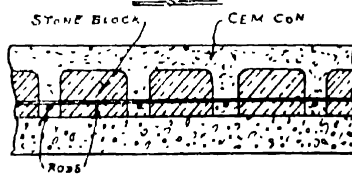
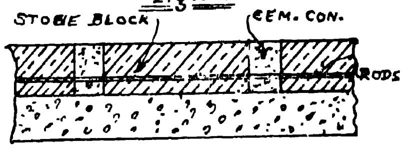


Fig. 10.



R.B.C. & R.C.

R.B.C. vs. R.C. R. B. C. slab equally stiff and strong as R. C. slab.

The strength and stiffness of reinforced brick concrete and reinforced concrete slabs with the same depth, the same proportion of concrete, the same reinforcement and the same age are the same for all practical purposes. Figures 11 and 12 show sections of two R. B. C. & R. C. slabs subjected to transverse loading. In both cases the tensile stresses developed are taken by the bottom steel and compressive stresses at the top by the concrete.

Fig 11

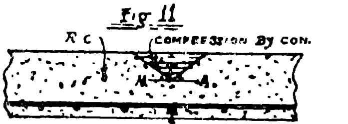
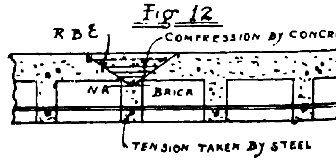


Fig 12



The elementary principle of R. C. is that tension is taken by the steel at the bottom and compression is taken by the concrete at the top. The tensile strength of the concrete at

the bottom is ignored. So theoretically the strength and stiffness of the two slabs should be the same.

Actual experiments carried out by the writer clearly showed that they are practically the same.

Long series of experiments were conducted by the writer on reinforced brickwork and concrete at several places in India for the last 22 years and the results of the experiments have been embodied in the writer's books on "Experimental researches on reinforced brickwork" and "Regulations relating to reinforced works—R.C., R.B. and R.B.C." Interesting experiments done.

In 1917 a very interesting set of experiments was carried out at Patna—a series of R.C., R.B. and R.B.C. beams were tested side by side with the same depths and the same reinforcements.

The beams were on 10′-6″ spans and of sections 10″ wide and 11½″ deep, reinforced with 2½″ dia. rods placed about ¾″ from the bottom. They were tested with concentrated loads on the middle thirds.

The beams were tested to destruction.

The experiments were as follows :—

1. R.B. Beam with bricks laid in 3 : 1 sand cement mortar.
2. R.B. Beam with 3 : 1 mortar but with hoop reinforcements at the centre.
3. R.B. Beam with 2 : 1 mortar.
4. R.B.C. beam with 3″ top concrete of 1 : 2 : 4 proportion.
5. R.C. beam with 1 : 2 : 4 proportion.

All these beams were of the same span, same section and same reinforcements.

Figure 13 shows the different sections of beams.

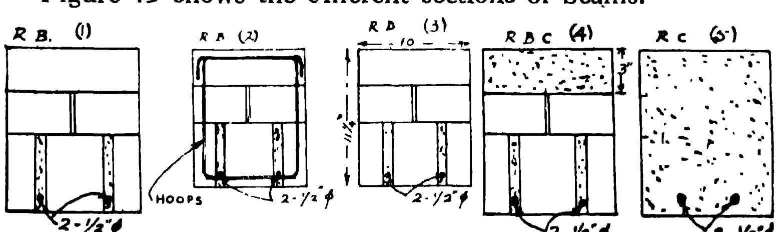


Fig 13.

The results of loading were as follows :—

	R.B. 1	R.B. 2	R.B. 3	R.B.C. 4	R.C. 5
Ext. load on Mid. 3rds in cwt. at first sign of failure cwt.	51·6	54·6	51·6	54·6	54·6
Corresponding deflection at centre of span in.	·4″	·52″	·45″	·35″	·35″
Ext. load on Mid. 3rds at failure in cwt.	61	64	61	64	64

These results show that R.B.C. and R.C. beams carried the same load with the same deflections and so they were equally stiff and strong. In some cases R.C. beams and slabs gave slightly higher results than R.B.C. beams and slabs. That was due to higher tensile strength of concrete than brick concrete.

portant conclusions.

We come to a very important conclusion from these experiments that R.B.C. and R.C. possess equal strength and stiffness but R.B.C. is much cheaper than R.C. as bricks, a least costly material of R.B.C., replace a major part of the costly concrete of R.C.

The method of calculations for determining the strength of R.C. and R.B.C. is similar.

B.B.C. AND CONCRETE.

B. C. vs. ncrete.

Bonded Brick Concrete (B.B.C.) is the same as cement concrete with bricks introduced in the lower part of the same. The upper concrete possesses the same tensile and compressive strengths in both the cases. In the lower part the combined strength of brick and concrete is between 2/3rds to ¾ths of the strength of all-concrete.

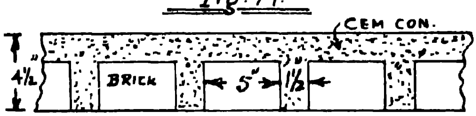
Cement concrete without reinforcements is often used for road construction. *B.B.C. can be safely used in preference to the cement concrete and a great saving can be effected thereby.*

compared.

Comparison of cost of 4½″ cement concrete with 4½″ R.B.C. Taking the cost of concrete @ Rs. 80/- per % c.ft. and of brick @ Rs. 16/- per 1,000, (10″ × 5″ × 3″ bricks) including cost of labour for laying.

Cost of $4\frac{1}{2}''$ cement concrete per 100 s.ft.				
$= \frac{4\frac{1}{2}'' \times 100}{12} = 37 \cdot 5$ c.ft. @ Rs. 80/- per 100 c.ft.	Rs.	30	0	0
Cost of $4\frac{1}{2}''$ B.B.C. per 100 s.ft.				
Bricks ($10'' \times 5'' \times 3''$) = 200 Nos. @ Rs. 16/- per 1,000	Rs.	3	3	0
Cement concrete $= 21\frac{3}{}$ c.ft. @ Rs. 80/- per 100 c.ft. ..	Rs.	16	13	0
	Rs.	20	0	0

Fig. 14.



Thus the cost of $4\frac{1}{2}''$ B.B.C. works out to Rs. 20-0-0 as compared with Rs. 30/- for all-concrete.

Not only B.B.C. and R.B.C. are cheaper than concrete and R.C., but they warp much less under heat and cold, and crack much less than concrete or R.C.

B. B. C. & R. B. C. crack less than concrete.

R.B.C. AND CONCRETE.

It is much more economical to use R.B.C. in place of plain concrete. The flextural strength of R.B.C. and of concrete is measured by their resisting moments. For the same depth R.B.C. possesses much greater flextural strength than plain concrete.

R.B.C. vs. Concrete.

Considering a foot width of slab the resisting moment of a concrete slab is given by the formula—

$$M = \frac{bd^2 \times f.}{6} \quad \text{or} \quad \frac{bd^2}{6} \times f$$

Where M = Resisting moment in inch-lbs.
b = Width of slab in inches.
d = Depth of slab in inches.
f = Safe stress of the concrete in lbs. per sq. inch.

Taking b = 12″ and f = 60 lbs. per sq. inch.

$$M = \frac{bd^2}{6} \times f = \frac{12d^2}{6} \times 60 = 120d^2.$$

rength of ncrete.

Depth of slab.	Resisting moment in in.-lbs.
4″	1920
5″	2430
6″	4320
7″	5880
8″	7680

The resisting moments of R.B.C. slabs are determined by formula $M = A_t f_t a$.

rength of B. C.

Where M = Resisting moment in inch-lbs.

A_t = Sectional area of steel per foot in sq. inches.

f_t = Safe stress of steel in lbs. per sq. inch = 16,000 lbs. per sq. inch.

a = Arm of resisting couple in inches = 5/6 × effective depth (Approx.).

Depth of slab.	Reinforcements.	Spacing.	Resisting moment.
4″	3/8″ dia.	7″	8064 in.-lbs.
4″	5/16″ dia.	7″	5472 „ „
4″	$\frac{1}{4}$″ dia.	7″	3528 „ „
5″	3/8″ dia.	7″	10752 „ „
5″	5/16″ dia.	7″	7296 „ „
5″	$\frac{1}{4}$″ dia.	7″	4704 „ „
6″	3/8″ dia.	7″	13430 „ „
6″	5/16″ dia.	7″	9120 „ „
6″	$\frac{1}{4}$″ dia.	7″	4704 „ „
7″	3/8″ dia.	7″	16180 „ „
8″	3/8″ dia.	7″	18816 „ „

The resisting moment of a 6″ concrete slab is 4,320 in.-lbs., whereas the resisting moment of a 6″ R.B.C. slab with 3/8″ dia. rods 7″ apart is 13,430 in.-lbs. i.e., about three times ; again for the same cost R.B.C. will give double resisting moment to that for concrete.

Cost. 6″ cement concrete per % s.ft. @ Rs. 100/- per % c.ft.	Rs.	50	0	0
4½″ R.B.C. of the same strength. Bricks—200 @ Rs. 16/- per 1000	Rs.	3	2	0
Cement concrete—21 c.ft. @ Rs. 100/- per % c.ft.	Rs.	21	0	0
Steel rods—2/3 cwt. @ Rs. 7/8/- per cwt.	Rs.	5	0	0
	Rs.	29	2	0

The cost of 6″ cement concrete is Rs. 50/-, whereas the cost of 4½″ R.B.C. is Rs. 29/2/-. That shows economy of R.B.C. over plain concrete in road construction.

How to make different depths of B.B.C. & R.B.C. roads.

Usually sizes of common bricks in India are 10″ × 5″ × 3″ and 9″ × 4½″ × 3″. In Bengal 10″ × 5″ × 3″ bricks are used.

We shall consider 10″ × 5″ × 3″ bricks.

Different depths of R. B. C & B. B. C. roads.

3″ B.B.C. or R.B.C.	a brick flat.
4″ ,, ,, ,,	3″ brick plus 1″ cement concrete.
4½″ ,, ,, ,,	3″ brick plus 1½″ cement concrete.
5″ ,, ,, ,,	3″ brick plus 2″ cement concrete.
6″ ,, ,, ,,	3″ brick plus 3″ cem. con. or 3″ brick flat with a mortar joint.
7″ ,, ,, ,,	a brick on edge (5″) plus 2″ cement concrete.
8″ ,, ,, ,,	2 bricks flat plus 2″ cement concrete.
9″ ,, ,, ,,	2 bricks flat plus 3″ cement concrete.

In case of 9″ × 4½″ × 3″ bricks different depths can be worked out as above.

Special bonding bricks :—Often it is more convenient to burn 10″ × 5″ × 4″ or thicker bricks with cavities (as shown in figs. 6 & 7) and use the same in road construction.

Bonding Bricks.

4″	a brick flat 4″ deep.
5″	a brick flat plus 1″ cement concrete.
6″	a brick flat plus 2″ cement concrete and so on.

10″ × 5″ × 4″ bonding bricks can be easily manufactured at a cost of about Rs. 14/- per thousand in India.

Reinforcements :—Reinforcing steel rods or fabrics are used for reinforcing bonded brick concrete roads.

Where reinforcements are used at the bottom, rods are used, as fabrics of standard dimensions are scarcely available in the market to suit the brick spacings, and where reinforcements are used in the top of concrete above bricks, both rods and fabrics can be used. Where the road bed is hard and there is very little chance of settlement, no reinforcements are ordinarily necessary. Where the road bed is new, it is necessary to consolidate well a layer of road metal before laying the B.B.C. pavements. Another object of using reinforcements in concrete road is to reduce the number of cracks. The use of reinforcements at the top, say $1\frac{1}{2}''$ to $2''$ below the surface of bonded brick concrete road, will produce satisfactory results in the cases of ordinary roads.

Good foundation......$\frac{1}{4}$ to $\frac{1}{2}$ cwt. per 100 s.ft. either at top or bottom.

Moderately good foundation......$\frac{1}{2}$ to 1 cwt. per 100 s.ft. at bottom generally.

Doubtful foundation......$\frac{3}{4}$ths to $1\frac{1}{2}$ cwt. per 100 s.ft. two-thirds at the bottom and one-third at the top.

In actual construction reinforcements had been used at the bottom and also at the top only with equally good results.

METHOD OF CONSTRUCTION.

Method of Construction.

(1) The existing surface of the road is levelled properly and rolled, pits filled up and unevenness removed by the use of some road metal consolidated with a fairly heavy road roller with proper watering.

In the cases of new roads $4''$ road metal with a brick soling may be used and the metal consolidated well by rolling. Over that R.B.C. can be used.

In the case of R.B.C. roads $3''$ to $4''$ well consolidated road metal can be used as a foundation for the roads.

(2) $\frac{1}{2}''$ sand is spread on the surface and wetted with water. In some cases no sand is used but bricks are laid in cement mortar on the foundation bed.

(3) Hard burnt first class bricks well wetted with water are spread on the foundation in case of sand layer below or laid in cement mortar on the foundation bed with gaps between the bricks as $1\frac{1}{2}''$ to $2''$ in usual cases.

In the case of R.B.C. roads, rods are first bound into network as $7'' \times 12''$ or $6\frac{1}{2}'' \times 11\frac{1}{2}''$ according to size of the bricks spread on the foundation $1''$ above the bed and inside the gaps between the rods bricks are placed. Joints are usually made $1\frac{1}{2}''$ to $2''$ or more as desired.

(4) Water is sprinkled on the bricks, and cement mortar of $1 : 2\frac{1}{2}$ proportion is grouted inside the joints in the case of R.B.C. In B.B.C. roads cement concrete of plastic consistency is placed inside the joints and packed well.

(5) Stiffer concrete of proper mix is laid on the top and the same is consolidated well by tamping as is done in the case of concrete roads.

(6) The surface is covered with wet gunny bags for 24 hours then water is stored by making mortar bunds on the road surface; wet mud, mosses etc., are also used for curing.

(7) $3''$ extra concrete is used at each edge of the expansion joints and at the edges of the floor.

(8) Expansion joints are to be provided at distances of $20'$ to $30'$ apart.

(9) In the case of concrete with brick or of any soft ballast it is preferable to use some concrete with hard stone ballast on the top.

(10) The surface is to be treated with 3 coats of Soda Silicate wash at intervals of 24 hours, 2 weeks after construction.

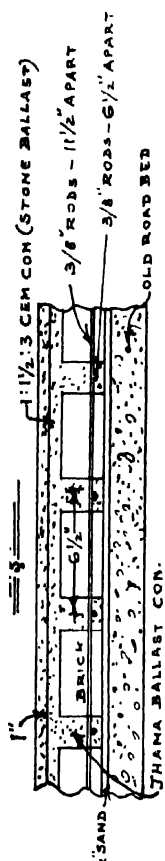
SPECIFICATION FOR A $4\frac{1}{2}''$ R.B.C. ROAD.

Barisal Municipality, Bengal. (See Fig. 15.)

Bricks. Picked first class, hard-burnt and straight. Picked jhama bricks are also used. Specification.

Cement. Portland cement of British Standard specification or Indian cement as Rohtas, Swastika, etc., will do.

If quick setting cement is wanted for the last few bays, Rohtas-crete or Swastika-crete may be used.



Sand. Clean coarse sand graded in size is to be used. For the lower course half part local Savor sand and half part coarse sand will do.

For the top of concrete only coarse sand is to be used.

Rods. Mild steel. Rods can be doubled without fracturing the outside fibres at the bends.

Jhama chips. Chips of picked brick jhama of gauge ½" down to 1/8". The ballast is to be washed and cleaned.

Measurement of cement. Cement in bags weighs one cwt and in volume it is to be kept as 1¼ cft. Cement is to be measured by weight and not by volume.

Stone chips. Hard stone chips of Pakur stone will do. The gauge will be ½" to 1/8". The ballast is to be washed and cleaned.

Water. 4 to 6 gallons of water per bag of cement. If the ballast and sand be wet, 4 to 4½ gallons will be found ample. The top concrete is to be made a bit stiffer.

Time. The top 1" concrete is to be laid within half an hour after the laying of the bottom layer.

Cost. The cost of B.B.C. & R.B.C. roads will vary from place to place according to the cost of labour and materials, the proportion of concrete, depth of the roads, quantity of concrete and bricks and also quantity of steel.

As a specimen analysis the following is given:—

Cost of 4½" R.B.C. roads as adopted at Barsial per 100 s.ft.

Analysis of cost

1. Preparation of subgrade by picking up bed, scarifying, regrading, rerolling, complete with ½" sand at the top — Rs. 3 8 0

2. Picked first class hard-burnt bricks including labour for laying—200 No. @ Rs. 17/- per 1,000 — Rs. 3 6 0

3. Cement concrete in joints and ½" above the bricks with picked jhama ballast of

	gauge ½" and down (1 : 2½ : 3½)—12½ c.ft. = Rs. 55/- per 100 c.ft.	Rs.	8 2	0
4.	1" cement concrete (1 : 1½ : 3) with Pakur stone ballast ½" gauge and down—8⅔ c.ft. @ Rs. 110/- per 100 c.ft.	Rs.	9 3	0
5.	Mild steel rod—2/3rd cwt. @ Rs. 7/- per cwt.	Rs.	4 11	0
6.	Expansion joints at every 20' and three coats of soda silicate wash (1 in 4) @ Rs. 1/8/- per 100 s.ft.	Rs.	1 8	0
	Cost per 100 s.ft.	Rs.	30 6	0
	Cost per s.ft.	Rs.	0 4	10

The accepted tender for the work was -/4/6 and over a mile of 4½" R.B.C. road was constructed at Barisal.

The cost of different sections can be worked out on similar lines.

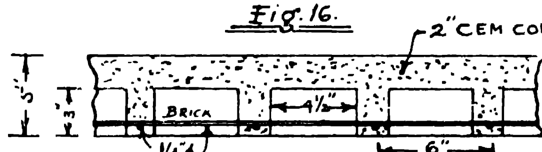
Maintenance. The maintenance cost of B.B.C. & R.B.C. roads is very low. It is just like all-concrete roads. Ordinarily -/4/- per sq. ft. in a year is quite sufficient. Generally the maintenance cost is incurred in filling up the expansion joints with asphalt, also in patching up any cracks with a little asphalt. A comparative statement of cost of different kinds of roads including maintenance is given in appendix No. 2. This statement clearly shows that the bonded brick concrete roads, plain and reinforced, are cheaper than other kinds of roads now in use in India. Maintenance.

Actual Construction. The actual construction of bonded brick concrete roads both plain and reinforced has proved that this form of construction produces very sound, durable and economical roads. These roads are equally efficient like all-concrete roads but are much less costly. When the cost of maintenance is taken into consideration the total cost of these roads is probably cheaper than that of any other kind of durable road now in use in India. Actual construction.

The author started laying a length of 700 ft. of 5" R. B. C. road in May 1930 at Yehiapur Road, Allahabad. 5" R.B.C. was made by combining 3" deep bricks (9"×4½"×3") with 2" Allahabad, May 1930.

top concrete with $1\frac{1}{2}''$ joints between the bricks. The reinforcements used were $\frac{1}{4}''$ dia. rods 6″ apart along the length of the road and $10\frac{1}{2}''$ apart crosswise (see fig. 16). The proportion of concrete was 1 : 2 : 3 with Sankargarh sand stone ballast. The work was done according to the author's directions by Allahabad Municipality, and Messrs. Mackenzies Ltd. of Bombay were the contractors. The work was in a satisfactory condition in 1937. Seven years had already passed. In addition to ordinary traffic a very large volume of rain water finds its way out into the Jumna river from that road. So whenever there is a very heavy shower, water flows over the road surface to a depth of about 2′-0″ or so with great velocity. Formerly water-bound macadam was used every year and that was washed away by the rushing water during heavy rains. The road as constructed at present, is quite satisfactory. Except at some expansion joints between the slabs there had been no other damages. Those joints had been repaired with asphalt concrete. It is to be noted that the upper concrete had not been separated from the lower brickwork and the whole thing had worked like one mass of 5″ depth.

Fig. 16.



Expansion joints were used every 16′-0″ apart and the surface was treated with soda silicate (1 in 4) wash. There had been some cracks at the middle of the slabs which had been repaired with asphalt. The subgrade was old road bed. It was in many places ordinary earth and in some places old road metal. Ordinary common Allahabad bricks $9'' \times 4\frac{1}{2}'' \times 3''$ were used. The cost was Rs. 42/12/- per 100 sft.

April, In April 1932 the Chief Engineer, P.W.D., Bengal, tried some experimental lengths of 6″ R.B.C., 6″ B.B.C. and 6″ R.B.A.C. roads at the 5th mile of Calcutta-Jessore road (near Belgachia Railway over-bridge). The condition of these Calcutta roads in July 1937 was perfectly satisfactory—just like the 7″ all-concrete road laid from Belgachia tram depot to that place. Wooden sign boards were fixed against such experimental lengths and they can be inspected now.

In these cases $10'' \times 5'' \times 4''$ bonding bricks were used.

EXPERIMENT NO. 1—6" R.B.C.

4" thick bricks with top 2" concrete and 2" joints between the bricks filled up with the same concrete. Reinforcement – 3/8" dia. rods—7" apart along length and 12" apart crosswise—placed 1" above bottom. Calcutta, 19

Proportion of concrete 1 : $1\frac{1}{2}$: 3 (Pakur stone ballast—$\frac{3}{4}$" to $\frac{1}{4}$" gauge used).

Expansion joints. 30'-0" apart.

Surface treatment. 3 coats of soda silicate wash 1 in 4 (after 3 weeks of setting).

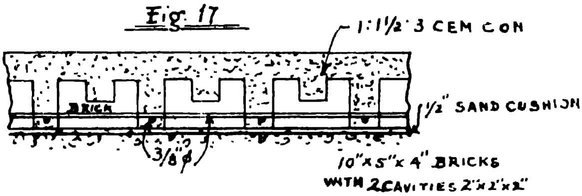
Width of slab. 18'-0".

In this experiment reinforcements had been used at the bottom and not at the top. The slab has stood quite satisfactorily for the last 5 years without any sign of deterioration.

The present condition of the road is ideal (July 1937).

Fig. 17 shows the section.

Fig. 17



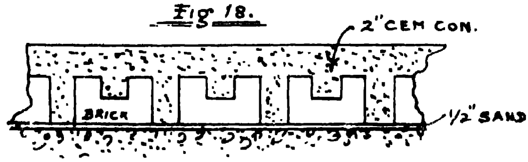
There are no cracks in the slab and there had been no trouble whatsoever in the same. Its behaviour is just like an all-concrete slab. The top surface being cement concrete, it cannot be distinguished from an all-concrete slab. In outside appearance both R.C. and R.B.C. roads are quite similar.

EXPERIMENT NO. 2—6" B.B.C. ROAD.

Particulars same as experiment No. 1 (see plate No. R/1) no reinforcements used.

Bricks laid break-jointed crosswise with 2" joints between them (see fig. 18). Calcutta, 193

Fig. 18.



Length of slab. 30′-0″.

Preparation of bed.—Old road bed, scarified and regraded.

Constructed. April 1932.

Present condition. (July 1937) Quite satisfactory.

Two fine expansion cracks developed which had been patched up with asphalt.

It is to be noted that in this case no reinforcements had been used whereas in the first experiment reinforcements had been used. Both the slabs are standing quite satisfactorily. In this slab two fine cracks developed whereas in other slabs no cracks developed. It appears that the reinforcing rods prevented the appearance of cracks in the first slab, otherwise there is no difference between the two.

EXPERIMENT NO. 3.—6″ R.B.A.C. (REINFORCED BRICKWORK ASPHALT CONCRETE).

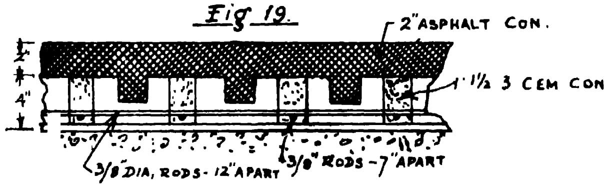
Calcutta, 1932. 4″ R.B.C. at bottom with 2″ grouted asphalt concrete surfacing.

(See plate No. R/1).

Here particulars of the lower 4″ R.B.C. are like those in experiment No. 1 and 2″ on the top and the cavities of the bonding bricks had been filled up with grouted asphalt concrete.

Asphalt used at 7 lbs. per sq. yd. (see fig. 19).

Fig 19.



Constructed. April, 1932.

Present condition. (July 1937) Excellent.

This experiment showed that the bonded asphalt concrete surfacing on an R.B.C. foundation made an excellent road. The foundation and surfacing worked together as one mass.

In 1933, the Municipal Engineer, Benares, tried a $4\frac{1}{2}''$ R.B.C. surfacing in the water works main road of the Benares Municipality.

Here the proportion of concrete was 1 : 2 : 4 with stone ballast and Gaya sand.

Area covered—761 sq. yds. Benares, 1

Cost—Rs. 1,633-11-6.

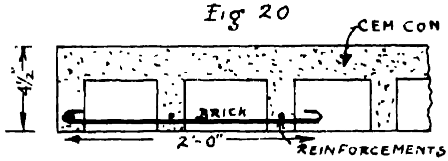
Cost per sq. yd.—Rs. 2-2-4.

Here reinforcing rods were used at the edges only and not in the central part. Expansion joints....30 ft. to 36 ft. apart. Constructed—1933.

Present condition in July, 1937— Excellent.

(See fig. 20).

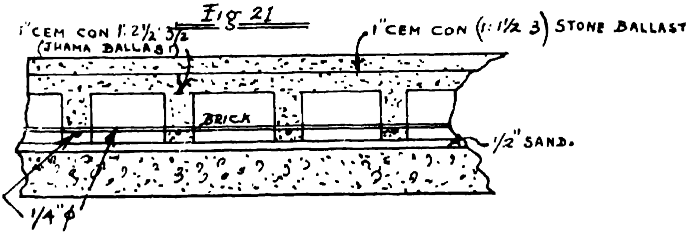
Fig 20



In August 1933, another road was constructed at Benares at Nepal Raj Palace called Kaisar Castle. Here two-course concrete was used. That was a 5″ R.B.C. road, 3″ bricks 1½″ joints and 1″ top cement concrete (1 : 2½ : 3½) of jhama ballast were used and another inch cement concrete (1 : 1½ : 3) on the top of the lower concrete with Chunar stone ballast was laid; both were laid at the same time in quick succession. Benares 1933.

The present condition of the road (in July 1937), *i.e.* 4 years after construction, is quite satisfactory. Fig. 21 shows a section of the road.

Fig 21



This experiment shows that economy in R.B.C. road is effected by using a cheaper ballast with weaker proportion of concrete below and a richer proportion of concrete on the top with harder and costlier stone ballast on top.

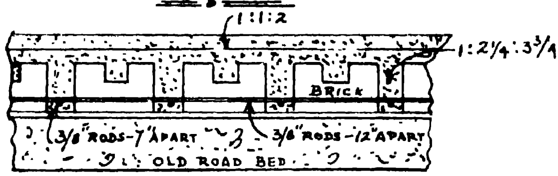
In 1934 the Chief Engineer, Improvement Trust, Calcutta, made two experimental lengths of 7″ R.B.C. at Jaggannath

Calcutta, 1934.

Ghat Road, each 32 ft. long and 17 ft. wide. The total width of road was 100 ft. and the traffic was very heavy. This was extension of Maniktalla Spur, Calcutta.

Experiment No. 7.—7″ *R.B.C.* Composed of 4″ bricks with 1 : $2\frac{1}{2}$: $3\frac{3}{4}$ concrete in joints and 1″ above top with 2″ top concrete on surface 1 : 1 : 2. Reinforcements used were 3/8″ dia.—7″ and 12″ apart crosswise at bottom. Fig. 22 shows a section.

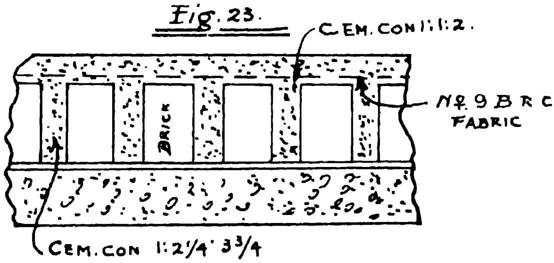
Fig. 22.



Experiment No. 8. Was done with 7″ R.B.C. composed of 5″ (brick on edge) bricks $1\frac{1}{2}$″ apart each way with no reinforcements at bottom but joints filled up with 1 : $2\frac{1}{2}$: $3\frac{3}{4}$ concrete and on the top of that 2″ concrete of 1 : 1 : 2 proportion was used. Reinforcements No. 9 R.B.C. fabric was used at top.

Fig. 23 shows a section of the road.

Fig. 23.



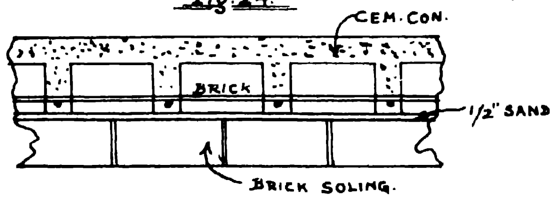
This was done in September, 1934 and the present condition (in July 1937) *i.e.*, about three years after, is ideal. There is no defect anywhere. It is like all-concrete 7″ R.C. road that was constructed by its side. From outside look it is not possible now to find out what is R.B.C. and what is R.C.

Road, ipara utta b) 1934.

In September, 1934, a $4\frac{1}{2}$″ R.B.C. surfacing was laid on a new road bed at Telinipara (Bhadreswar Municipality) Bengal. This was done in connection with the widening of the Mill Road for a length of about 500 ft. That was done with $4\frac{1}{2}$″ R.B.C. with $\frac{1}{4}$″ dia. rods 7″ apart along length and 12″ apart crosswise, with the proportion of concrete as 1 : $2\frac{1}{2}$: $3\frac{1}{2}$ with

stone ballast. The present condition of the road (in July 1937) is quite satisfactory. Figure 24 shows a section of that road.

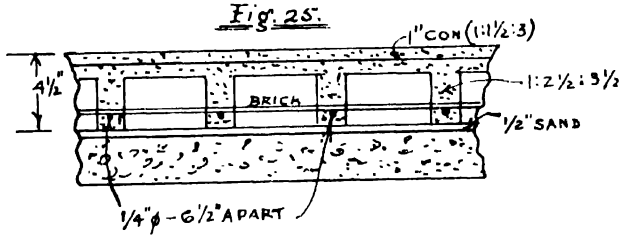
Fig. 24.



Hospital Road at Barisal was covered with $4\frac{1}{2}''$ R.B.C. in April 1934, according to author's design and specification. $4\frac{1}{2}''$ R.B.C. road was made by using $3''$ deep bricks with $1\frac{1}{2}''$ joints with $3/8''$ dia. rods $11\frac{1}{2}''$ apart across the road and $\frac{1}{4}''$ dia. rods $6\frac{1}{2}''$ apart along the road. Cement concrete with picked jhama ballast of proportion $1 : 2\frac{1}{2} : 3\frac{1}{2}$ was used in the joints between the bricks and $\frac{1}{2}''$ above the bricks and the remaining $1''$ at the top was done with richer cement concrete $1 : 1\frac{1}{2} : 3$ with harder Pakur stone ballast ($\frac{1}{2}''$ gauge and down). Barisal 1934.

Figure 25 shows a section of the road.

Fig. 25.



A length of 500 ft. was done with $4\frac{1}{2}''$ R.B.C. at a cost of -/4/5 pies per sq. ft. or Rs. 2/8/- per sq. yd.

The condition of that road in July 1937, *i.e.*, 3 years and 4 months after construction was perfectly satisfactory. The maintenance cost was practically nothing.

The Barisal Municipality then laid $4\frac{1}{2}''$ R.B.C. at the Sadar Road for a length of 300 ft. in 1934 and the condition in July 1937 was quite satisfactory.

In 1935 a $4\frac{1}{2}''$ R.B.C. road with $\frac{1}{4}''$ rods as reinforcements was constructed at Bengal Immunity Laboratory, Buranagore, Calcutta. The present condition is perfectly satisfactory. B. I. Laboratory 1935, Calcutta.

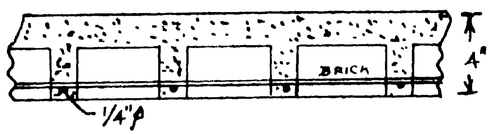
In April 1936 the Barisal Municipality laid the Collectorate Road with $4\frac{1}{2}''$ R.B.C. for a length of 1,500 ft. and width Barisal 1936

12′ 6″. The reinforcements and other particulars were the same as those for Hospital Road. Here some of the expansion joints had to be levelled with a little asphalt. The present condition is quite satisfactory.

Another road known as Chowk Bazar Road (Barisal) was completed with $4\frac{1}{2}''$ R.B.C. in the same year for a length of about 2,000 ft. The tendered rate was -/4/6 per sq. ft. The present condition of the road is perfectly satisfactory.

Areadah 1936. In 1936 in Kamarhati Municipality 4″ R.B.C. surfacing with $\frac{1}{4}''$, $6\frac{1}{2}''$ and $11\frac{1}{2}''$ crosswise was done at Satish Mallik Lane, Areadah. The proportion of concrete was 1 : 3 : 4 with Pakur stone ballast. Fig. 26 shows a section of the road.

Fig. 26

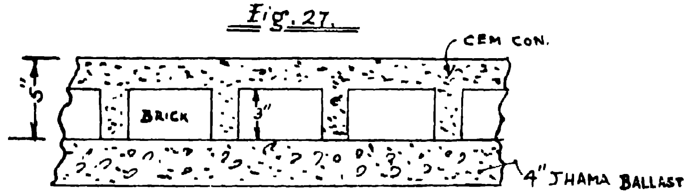


The present condition is ideal. It is to be noted that only 1″ concrete surfacing had been used on the top of the bricks.

Lucknow 1935 The P. W. D., Lucknow laid a 5″ B.B.C. road at the University Road, partly on old metalled road bed and partly on old *kutcha* (unmetalled) road bed in December, 1935.

Fig. 27 shows a section of the road.

Fig. 27.



On the unmetalled portion 4″ Jhama metal was laid and consolidated with a steam road roller. Over the old and new bed 5″ B.B.C. (3″ bricks with $1\frac{1}{2}''$ joints and 2″ top concrete) was laid. No reinforcements were used. The present condition of the road (in July 1937) is perfectly satisfactory.

The Dacca District Board laid a 5″ R.B.C. road on Dacca-Narayangunj Road in March 1937; reinforcements were 3/8″ dia. $11\frac{1}{2}''$ apart and $\frac{1}{4}''$ dia. $6\frac{1}{2}''$ apart crosswise. The work had to be done on a new filling of 2 ft. to 4 ft. earthwork.

Further investigations on economising in concrete road construction are in progress now.

DEHRA DUN WATER SUPPLY— BANDAL NADI EXTENSION

BY

HAR GOVIND TRIVEDI, Associate Member.

The water supply to Dehra Dun, before the Bandal Extension Scheme was completed, was not only precarious but also defective in that the supply was restricted, more than half the population receiving water of a considerable degree of hardness, which was unpalatable and disliked by the public. **Introduction**

The supply was obtained from three sources :—

(I) KOLUKHET SPRINGS.

These springs are situated about 15 miles from Dehra Dun on the Mussoorie motor road, and have, during the last 40 years, been the main source of supply of potable water to the town. The supply is by gravity through two mains, one a 3″ pipe line, which runs to Dehra Dun *via* Rajpur. This line used to supply water to a large portion of Dehra Dun, besides Viceroy's Bodyguard, Military Officers' Bungalows on the Rajpur Road and Rajpur Town, which are all outside the Municipal limits. The other line, which is $2\frac{1}{2}''$ in diameter, and runs along Hathibarkala, supplied water to the Government Circuit House and other localities. It terminates near the Post Office, where it joins the Rajpur Dehra pipe line.

The yield from these springs varies from 90 gallons per minute during summer to 150 gallons per minute during the rains, and the hardness of the water from 20 to 22 parts per 100,000.

(II) NALA PANI SPRINGS.

These springs are situated about 3 miles from Dehra Dun. Their yield is, however, very small varying from about 10 gallons per minute during the hot season to 25 gallons during

the rains. The water is particularly soft, varying in hardness from 6 to 8 parts per 100,000, and so it is very popular with the consumers.

The supply is by gravity, and is collected in two reservoirs in Dehra Dun, where there is generally a crowd of people, struggling to obtain a supply.

(III) BALDI SPRINGS.

Up to the year 1924 Kolukhet and Nala Pani Springs were the only two sources of supply in Dehra Dun and acute shortage was felt during the dry season.

To relieve the shortage, the Municipal Board turned to the Baldi Springs, even though it was known that the water from this source was very hard. This supply, which varies from 120 gallons per minute during the rains to 70 gallons per minute in the dry season, was made available in 1926. The hardness of this water varies from 40 to 80 parts per 100,000.

As it was realised that this water was very hard, the distribution of the supply was arranged so that the various waters should not be mixed together, because the addition of the hard Baldi water to the other supplies would result in the whole supply being unpalatable due to excessive hardness. Accordingly, the eastern parts of Dhera Dun received the hard Baldi water and the Kolukhet supply was distributed to the thickly populated western portion of the Town as well as to Rajpur and some habitations on the Rajpur and Dehra Dun roads.

The Baldi water due to its hardness had been unpopular from the start and innumerable complaints had been registered concerning it. In 1929 a contract was placed with a firm of water purification specialists for installing a water softening plant to treat the supply. Unfortunately their efforts were not successful. Experiments proved that the water would only re-act to a limited extent to the treatment and even so, the cost of chemicals worked out at about three times the guaranteed figure. In consequence of this failure, the suppliers of the softening plant agreed to remove it and compensate the Municipal Board to the extent of Rs. 10,000/- towards the cost of building work in connection therewith.

It will be realised that the supply from all these sources is at its lowest during the hot months—April to June, when the demand is at its maximum. The total supply at this time of the year is only about 170 gallons per minute, which gives a supply of about 6 gallons per head per day, taking the population of Dehra Dun and Rajpur at 42,000 only. This is a very small allowance per head of population and there was much distress during the hot months in consequence.

Sources that have been investigated.

Due to the paucity and character of the water supplied, many alternative sources of supply have been investigated by the authorities concerned since the inception of the Baldi Supply.

To the layman, it is probably a source of surprise that the problem had not been solved before as there is an abundance of water in the neighbourhood of Dehra Dun. Unfortunately most of the water available is very hard and it was considered undesirable to supplement the supply from these sources.

Some years ago a proposal was considered for taking water from the river Tons, but it was not proceeded with due to the hardness of the water. The experiment in softening the Baldi water proved that the softening process is by no means an easy one and the cost would be prohibitive for the full supply required for Dehra Dun.

There are some good springs near Mothrawala approximately 5 miles south of Dehra Dun and an estimate was prepared for taking a supply from this source. It was found that the water would have to be lifted at least 450 feet and this would involve the installation of pumping plant and the consequent heavy recurring charges. This source however is always available, should the Town require to supplement the present supply.

In 1933 the Board of Public Health gave a grant of Rs. 25,000/- for the construction of an experimental tube-well. This well was sunk to a depth of about 480 feet but the water level remained at about 310 feet below ground. On account of this it was not practicable to test the well without the aid of a special pump, which was not available and so it was not possible

to arrive at the yield, upon which to base the capacity of the pumping plant. Pumping from this depth would also have been very expensive. As only a very limited supply could be obtained, it was not considered worth while proceeding further in the matter and the experiment was abandoned.

BANDAL NADI.

So far the supply from springs only had been investigated, and as the water was found to be very hard, attention was diverted to the river supply. Tests carried out on Bandal water showed that the hardness varied from about 11 parts per 100,000 during rains to 20 parts per 100,000 during the dry season. The bacteriological tests showed that the water would require chlorination and also filtration during the rains due to its turbidity. On the whole, the water was pronounced to be fit for domestic use provided it was chlorinated and filtered.

This river is under the control of the Irrigation Department, and nearly all the water is taken for irrigation purposes. It was only after prolonged negotiations that the Irrigation Department agreed to allow one cusec from this source to be taken on a payment of Rs. 5,000/- per annum.

Of all the sources of supply investigated, the Bandal Nadi was the one most favoured by the Dehra Dun Municipal Board. Consequently a detailed project amounting to Rs. 5,54,982/- was prepared by the Public Health Engineering Department and submitted to the Board for approval and subsequently sanctioned by the Board of Public Health. Tenders were invited and the work of construction taken in hand in November 1935.

Before describing the new works in detail, it is necessary to explain the method adopted for utilising the existing supplies to the best advantage and as supplementary to the new supply.

(i) The Baldi water is of such an excessive degree of hardness that it is considered unfit for domestic use and will be used for drain flushing only. The works necessary to accomplish this object, though not originally included in the sanctioned estimate, have actually been carried out in this scheme from savings on the estimate.

(ii) The discharge from Nala Pani is very limited and as this water, on account of its great softness, is still in great demand, the supply will be left intact and not mixed with the supplies from other sources.

(iii) The Kolukhet water and the new Bandal supply will constitute the main source of supply and as there is considerable variation in levels, zones have had to be arranged to give equitable distribution throughout the town to enable the water to be used to the best advantage.

A diagrammatic sketch (Drawing No. 1) is attached, and this will enable the requirements to be more easily followed. Zones of supply.

As the filtration works of the Bandal supply are situated at Dilaram Bazar, the area, which this source can command, will necessarily be below the Dehra Dun Club, for, above the Club, a minimum pressure of 20 feet will not be available.

For the purpose of distribution it has therefore been necessary to divide the town into three zones. The high and the intermediate zones will be supplied from the Kolukhet springs, and the low zone from the Bandal supply.

The population to be supplied in the different zones is give below :— Population.

Kolukhet :	High Zone	.. ..	4,124
	International Zone	..	8,613
Bandal :	Low Zone	.. ..	30,893
		Total ..	43,630

As the Irrigation Department have limited the supply from the Bandal Nadi to one cusec and as during summer the discharge from the Kolukhet springs decreases considerably, the total available supply from both the sources works out at approximately 16 gallons per head per day, which cannot be considered a liberal figure for a growing town like Dehra Dun. In order to conserve this limited supply, it has been decided to give private connections only through meters. Supply *per capita.*

Distribution.

These works do not include any reorganisation of the existing distribution, except such works as are necessary to carry out the zoning indicated above.

The present system of supply is that the water is collected in small storage tanks situated along and at the ends of the distribution pipes, and the consumers draw their water from these tanks. There are very few private service connections, and before these can be given at a liberal scale, the distribution system will have to be reorganised and extended. An estimate for this work amounting to Rs. 2,72,274/- has recently been sanctioned and tenders have been invited, and it is hoped that a complete distribution system will be ready by the next summer.

DESCRIPTION OF WORK.

Headworks Bandal supply

The site of the headworks is located on a suitable strip of land on the right bank of the Bandal Nadi at a distance of about 900 feet above the existing canal headworks.

Photograph No. 1 indicates generally what has been done in this connection.

In the sanctioned estimate it was proposed to construct a low masonry dam, but on investigation it was found that a temporary bund made of boulders would serve the purpose just as well, and would be cheaper to replace in the event of its being washed away by floods, which are exceptionally heavy in this river during the monsoon.

The entrance to the intake is protected by two grids against heavy boulders that are usually brought down by the river during storms.

As the Irrigation Department rightly demanded that suitable provision be made for measuring the amount of water that will be taken by the gravity main from the headworks, a stilling basin with V-notch and a Vernier hook gauge have been provided. To further restrict the supply to only one cusec, a module has also been fixed in the 10″ gravity main just opposite the headworks of the Irrigation Department.

The headworks were brought into use at the beginning of May 1937, and they have stood quite a severe test, as the rains during the last monsoon were much above the average. In

one spate the water level very nearly reached the top of the walls of the stilling basin, and shifted a very huge boulder at the end of the outlet channel. Every storm brings down a lot of *bajri* which collects in a heap between the two grids and extra labour has to be employed during the rains to keep the channel clear.

Stewards and Lloyds steel pipes, coated both inside and outside with bituminous solution and wrapped with hessian cloth previously immersed in a bath of the same solution, have been used for the 10″ gravity main, which is 42,467 feet long. The joints are long sleeve spigot and faucet throughout, except in three places where plain steel pipes with Johnson's couplings have been used. **Gravity main.**

This pipe line is under a head of 165·5 feet and its theoretical discharge should be about 520 gallons per minute. On actual test, however, with the module full open, it gave a little more than 1·5 cusecs. If, therefore, when the demand arises, the Municipal Board can arrange for an additional half cusec of water, no further expense will need to be incurred on supplementing the gravity main.

The alignment of the pipe line is shown in Drawings Nos. 2 and 3.

From the section it will be seen that there were a number of difficult portions to be negotiated, of which only two will be mentioned here. One is near Maldevta, where the pipe line runs close to the covered canal. Here it was found necessary to construct a long retaining wall, illustrated in photograph No. 2, as it was considered that isolated masonry piers would not be strong enough to bear the impact of the heavy boulders, that are brought along by the Song river. This proved to be only too true as in subsequent rains not only heavy boulders were brought down but also a good deal of scour took place at this place. Further, in this length, damage by rolling boulders from the hill had also to be provided against, and for this reason pipes with plain ends and Johnson's couplings have been used and a cover of heavy concrete blocks has been provided over the pipe line.

The other place is where the pipe line crosses Baldi Nadi. Here it has been laid 10 feet below the bed of the river. In some places very heavy boulders had to be cut through during

the excavations. From inquiries it has been found that scour does not take place to any great depth and the pipe line at about 8 feet below the bed should be quite safe. As a matter of fact, the 6″ Baldi pipe line crosses the river further up in a similar manner, and it has been functioning for the last 10 years without any trouble.

Necessary air valves, scour valves and other specials have been provided at suitable places and wherever necessary.

WORKS AT DILARAM BAZAR.

Filtration Plant.

The building to house the filtration plant has been designed according to Messrs. Candy's requirements, who were successful in obtaining the contract for the filtration and sterilization plant.

The filtration plant is the most up-to-date plant yet installed in these Provinces, and as it forms a special feature of the scheme, it is described somewhat in detail.

The building and the arrangement of the filtration plant are shown on photographs Nos. 3, 4, 5, 6, 7 and 8.

Raw water is delivered at the filtration plant from the Bandal Nadi at the rate of 1 cusec, this quantity being controlled at the headworks by means of a module. Flow at this rate keeps the pipe line clear of silt.

Inlet to the filter plant is controlled by means of a float operated equilibrium valve, which ensures that the input to the plant is balanced with the output, without any possibility of flooding, under all variations of the working conditions on the plant.

As, however, it is not anticipated that it will always be possible to deliver the full one cusec to the supply system, an automatic overflow has also been provided at the inlet to the plant. This control is governed by the outlet level from the settling tanks and ensures that any water in excess of that being taken by the filters is automatically run to waste.

The raw water then passes through a venturi flume, which operates a flow Indicator, Recorder and Integrator supplied by Messrs. British Pitometer Co., and also provides the necessary control for the automatic chemical proportioners.

The venturi flume, originally designed for use in irrigation projects, has been largely developed by Messrs. Candy Filters (India) Ltd., for use in conjunction with filtration plant, as not only does it provide the necessary control for the flow recorder and chemical plant, but also provides a very satisfactory preliminary mix of the chemicals with the raw water in the standing wave on the downstream side of the flume—chemicals being added at the flume float. These advantages are obtained with a much less loss of head than is possible when a weir and mixing race are employed; the head loss, in the case of Dehra Dun, being only 6" at maximum flow.

The raw water from Bandal Nadi varies seasonally from a reasonably clear to a highly turbid water. Total hardness varies from 10 to 20 parts per 100,000, being part temporary and part permanent, total dissolved solids and alkalinity also vary appreciably and the water is liable to animal pollution.

As a result of comprehensive tests carried out by Candy Filters, the plant has been so arranged that the chemical treatment can be carried out by the addition of ferrous sulphate or sulphate of alumina alone or with, when required, either soda ash or sodium aluminate in addition.

The chemicals are prepared in concrete solution tanks fitted with hand operated agitating gear, four tanks in all, having been provided.

Automatic proportioning of the dose is obtained by means of Candy Miniature Weir Type Proportioners installed in duplicate. The proportioner consists of a miniature weir working in a mercury seal, so that its operation is practically frictionless, and carried in a rubber lined steel chamber. The level of the chemical solution in the weir chamber is maintained constant by means of two balancing boxes in series and the sill level of the miniature weir below the level of the solution is varied according to the flow through the venturi flume by means of float mechanism, governed by the level on the upstream side of the flume. The dose is, therefore, maintained in exact proportion to the flow. Adjustment of the dose is carried out by varying the width of the miniature weir sill—a special vernier control being provided for this purpose.

The importance of efficient aggregation of the alumina hydroxide floc is now being more fully appreciated, not only because it reduces the chemical consumption but also because more complete subsequent settlement is obtained.

The chemically treated water is, therefore, delivered to special aggregating tanks of the hopper bottom type, which have been extensively developed and employed by Candy Filters for this purpose.

The water is delivered to the bottom of the tank at relatively high velocity, thereby ensuring that the water is brought into intimate contact with a film of the sludge that has already been deposited, as research has shown that this provides a degree of aggregation only otherwise obtainable with mechanical flocculators.

The water then rises vertically upwards at decreasing velocity, which is low enough to eliminate any but very finely divided particles, and is finally collected in special decanting channels which reduce the possibility of short circuiting to a minimum.

The slopes of the hoppers are those which research has shewn to be necessary to ensure that the sludge does not stick to the sides and the tanks are desludged, as and when required, under hydrostatic head without interrupting the working of the plant. While the practical considerations involved in the design of these tanks and their equipment are of the greatest importance, there is no doubt that, when correctly designed, the results are excellent, the loss of head is extremely low, no external power is required, desludging is simple and very effective and the chemical consumption is also low. As the sludge discharge is visible, no unnecessary water is wasted.

The second stage consists of pure settlement only, the flow being horizontal, and the tanks being again provided with hopper bottoms for hydrostatic removal of the sludge.

The settled water is then delivered to two Candy Patent Rapid Gravity Filters, each having a nett filtering area of 150 square feet and designed for a combined output of 550,000 gallons per day at a filtration rate of 76 gallons per square foot per hour. A third filter will be added later when the demand increases.

Candy Patent Filter Floors are installed, these floors consisting of special earthenware pipes built into a reinforced concrete floor at 6" centres and carrying Patent Nozzles for collection of the filtered water and for even distribution of the washwater used for scouring. The floors are entirely non-corrosive and, once installed, need never be touched.

The nozzles, of which there are 4 per square foot, can be removed for inspection at any time, if required.

A separate air header, with phosphor bronze laterals, is carried above the filter floor for even distribution of the air used during the scour. Water is admitted through a hand operated penstock to a special bay whch distributes it evenly over the filter without any possibility of furrowing the sand.

The filter outlet is controlled by a Candy Module, which can be set to any required output and maintains this output constant irrespective of any variations in the inlet and outlet heads on the filters or loss through the sand bed.

Air, washwater and washout are controlled by hand operated valves or penstocks.

It is a well-known fact that, after washing, a filter is not working at its maximum efficiency for an appreciable period, depending upon the state of the raw water. Each filter is, therefore, provided with a Candy Patent Slow Start Controller, which brings the filter slowly and automatically from no output to full output in any desired period without any attention on the part of the filter operator.

The loss of head through the filter is indicated continuously on a differential loss of head indicator so that the operator knows immediately when washing is necessary.

The filters are designed for the latest Candy Patent washing system, which is claimed to give an exceptionally clean filter with a very low washwater consumption. From the tests carried out at Dehra Dun, these claims appear to be fully justified.

It is now universally agreed that the intensive rubbing action between the grains of sand, necessary to remove the adherent dirt, can best be produced by the simultaneous application of air and upwash, the latter at a relatively low rate. This is done on the Candy system and, to avoid carrying away of the sand, the water is stored above the sand bed. After agitation the air scour is shut off, air is cleared from the bed by the use of upwash at a higher rate and the dirty water is discharged rapidly to waste over a washwater weir at a height of approximately $4\frac{1}{2}''$ above the sand.

Final removal of the washwater, remaining above the sand, is carried out by a surface flush of unfiltered water, which drives this dirty water before it to the washwater weir, where it is discharged to waste.

The washwater, otherwise required to remove the final dirty water from the bed, is therefore saved and the sand is left in an exceptionally clean condition, the surface flush being most impressive to watch.

The washwater consumption at Dehra Dun, over a trial period of three months, which included the monsoon when the raw water was very turbid, was 0·34%, this water being measured and recorded by a special meter provided for the purpose.

Washwater is delivered from Mather & Platt pumps from a filtered water sump below the machinery room floor and the rates of upwash are checked by the meter referred to above.

Air is provided by Nichols Rotary Air Blowers, which supply the correct quantity of air at the required pressure direct to the filters, so that the quantity delivered is not left to the judgment of the filter operator.

All the filter controls are mounted on marble topped control tables to centralise and simplify operation of the plant. Push buttons for starting and stopping the pumps and compressors are also mounted on these tables.

Final sterilization is by the chloramine process, the ammonia and chlorine being added by a Candy Gas Ammoniator and Chlorinator respectively. The Chlorinator is of the Company's Chlorexchange type, which changes over automatically from

the used to the new chlorine cylinders without the necessity of checking the quantity of chlorine remaining in the cylinders It is considered that this control reduces supervision and waste of chlorine considerably. Thorough mixing is obtained by the installation of a series of baffles in the sump, below the machinery room floor, to which the filtered and sterilized water is delivered before being discharged to the clear water reservoir, the discharge to which is again measured by a British Pitometer Proportional Venturi Meter.

An interesting refinement is the provision of a Candy Clortes, which takes samples of the sterilized water automatically at regular intervals and indicates to the operators whether or not the water is being correctly treated.

The design of the plant as a whole is very compact and building costs, for the capacity involved, are economical.

The complete installation was carried out by Messrs. Candy Filters (India) Ltd., who also ran the plant for three months and supplied the necessary equipment for determining hardness, alkalinity, pH value, residual chloramine and clarity of the water; these tests are now being carried out by the staff as a matter of routine.

Balancing tank.

In place of a small high service tank for storing water required for the chemicals used in the plant, a fairly large tank of a capacity of about 14,000 gallons has been constructed. This will be filled by the wash water pumps and will supplement the supply to the intermediate zone, when the Kolukhet supply falls too low to meet the demand during summer.

This tank, which is seen in photograph No. 4, was very useful during the last monsoon, as a portion of the Kolukhet line was twice washed away. Consequently, if this tank had not been available, a portion of the town would have been without water for sometime.

Sludge drain

During the construction of the works, it was decided to utilise the Baldi water, which will no longer be required for domestic supply, for drain flushing. The Municipal Board

has already a storage tank of about 100,000 gallons capacity close to the Post Office, and this is filled, when required, from the Canal supply at a charge of Rs. 3,500 per annum for the purpose of drain flushing. The Baldi water will now be used in place of the Canal supply and some economy effected. Consequently a 6″ sewer has been laid from Dilaram Bazar up to the Post Office tank and the Baldi supply diverted into it. This sewer also serves the purpose of carrying away the wash-water and the sludge from the filtration plant.

Storage reservoir.

The capacity of the storage reservoir, which is seen in the foreground in photograph No. 3, is half a day's storage, *i.e.*, 275,000 gallons. It has been divided into two portions, and the maximum depth of water in it will be 10 feet.

After the works started functioning, it was found that the discharge from the chloramine apparatus was not readily mixing with the filter effluent, hence a few baffle walls had to be added, due to which great improvement has been effected as far as this complaint is concerned.

Supply mains.

Two lengths of supply mains, comprising 12″ and 6″ diameter cast iron pipe lines, have been laid from the filter house. These have been connected to the old distribution system and have supplied filtered Bandal water through the existing tanks to the low zone from the beginning of May 1937.

Reorganisation of the Kolukhet supply.

In the sanctioned estimate provision was made for re-placing the old 3″ Kolukhet Rajpur line with a 4″ main, and constructing a 20,000 gallons tank at Rajpur together with some other small works.

During the course of construction, it was decided to construct only the 20,000 gallons tank at Rajpur and to shift the Kolukhet chlorinating plant from its present site to the springs. This last work was necessary, as about 150 feet of head had been lost by the installation of the existing chlorinating plant. These works are in hand, but as they are not yet quite complete the drawings or photos have not been attached.

Other works, such as chowkidar's quarters, shed, latrine, urinal, godown, workshop, etc., have also been constructed and these do not require any special mention. Other works

The cost of the different works is noted below in round figures. Cost.

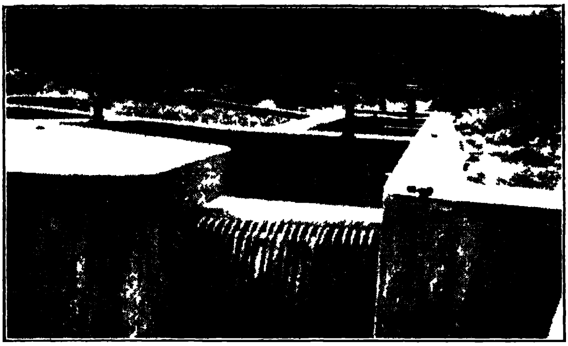
		Rs.
1.	Headworks ..	27,700
2.	10″ Gravity Main ..	2,53,400
3.	Works at Dilaram Bazaar—	
	(a) Filter Station Building ..	49,100
	(b) Filter Plant ..	82,000
	(c) Service reservoir ..	41,300
	(d) Washwater and sludge drain from filter house ..	25,300
	(e) Other small works ..	13,000
4.	Distribution Mains ..	42,200
5.	Reorganisation of Kolukhet Supply ..	21,000
	Total Rs. ..	5,55,000

As the Municipal Board have taken a loan @ $4\frac{1}{2}\%$ compound interest, payable in 30 years, to meet the cost of this scheme, the cost of water including sinking fund and interest and other maintenance charges works out to nearly annas four per thousand gallons.

The scheme was designed by the Public Health Engineering Department of the United Provinces Government and the construction has been carried out by my Division. The work was split into two contracts—Building and pipe

work, value approximately Rs. 4,00,000/-, carried out by Messrs. Thakur Kundan Singh of Dehra Dun, and the installation of rapid filters and sterilization plant, value Rs. 72,810/-, supplied and installed by Messrs. Candy Filters (India) Ltd., Bombay.

Mr. Ulfat Rai, who had Hardwar works also to supervise, was the Assistant Engineer in charge of the work. He was helped by two Overseers—B. Rup Chand Jain, who surpervised the works in Dehra Dun, and B. Gopi Lal, who looked after the Headworks and the gravity main.

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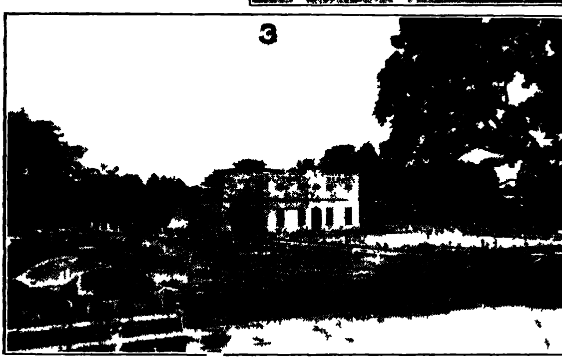
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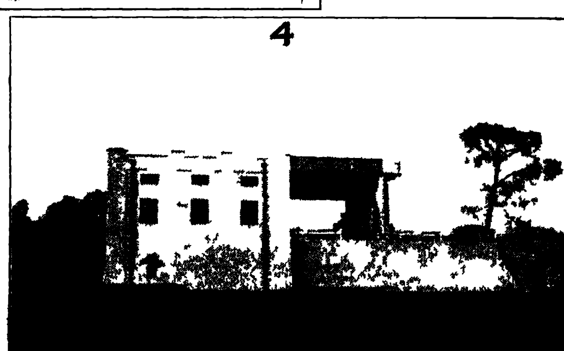
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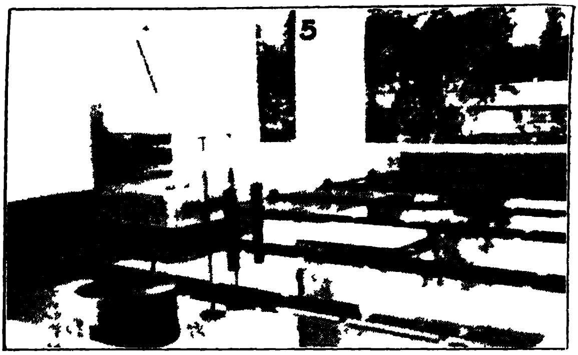
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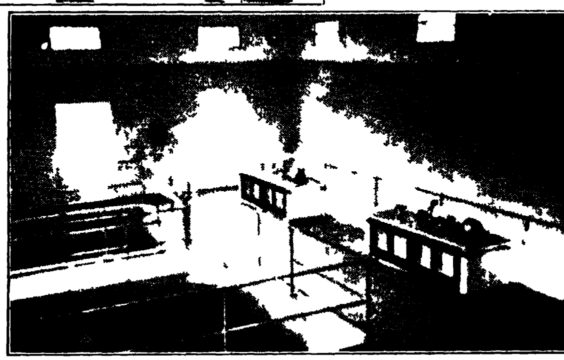

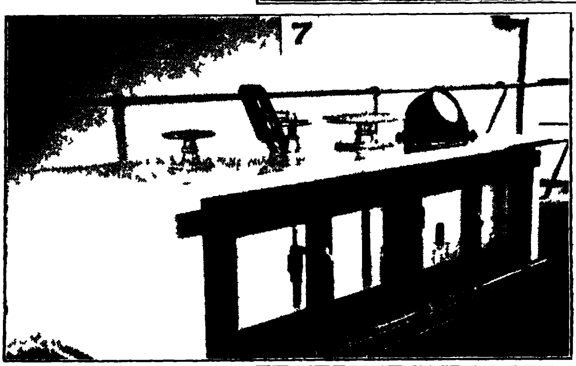
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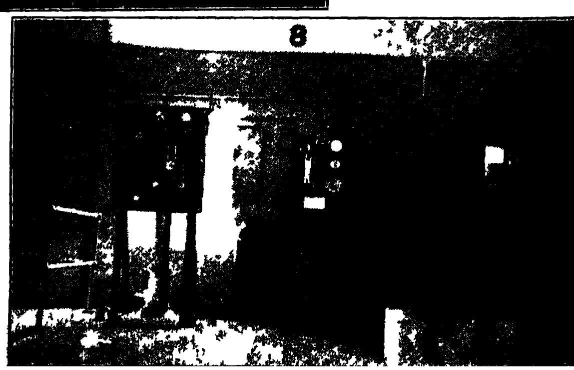
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ENGINEERING IN THE INDIAN PAPER INDUSTRY

BY

A. R. BEATTIE, Member.

Introductory :—

The art of paper-making is undoubtedly one of the most important industries of the present day. The study of its development since the early middle ages, when paper made its appearance in the countries of western Europe, is both interesting and instructive. The progress made by mankind in consequence of its introduction has been enormous. We have only to imagine that we still had to write on tablets, papyrus and parchment, to recognise at once that, if these were the sole writing materials at our disposal, it would not be possible to keep a record of achievements in science and arts nor to communicate them to all the centres co-operating in world—educational, administrative and commercial—circles, as we know them to-day. This provides us with an excellent example, as to how the practice of engineering—as applied to paper-making—has influenced in the highest degree the progress of one of the great industries of our time.

The most rapid development of the industry in the early use of machinery appears to have taken place in Holland, where windmills undoubtedly served a useful purpose in providing the paper-maker with an excellent means of driving his plant. Waterwheels seem to have been more extensively used in other countries, but both methods serve as an early example of the direct rotary drive. The invention—somewhere around 1690—of the *Hollander* beating engine, a simple yet ingenious machine that is deservedly known by the name of the country of its origin, gave a tremendous impetus to paper-making, as by its means the quantity of material which could be treated in twenty-four hours was greatly increased.

Paper itself was still being made by hand, as had been the custom for centuries, highly skilled craftsmen being employed for the purpose. For hand-made papers the stuff had to be taken from the vat by means of the *mould* for each sheet separately, and the sheet then dried between pieces of felt. The introduction of a continuous production flow was created by the invention in 1802 of the paper-making machine.

It might be said that the development, in improved methods of manufacture began with full force when steam power was generally introduced. Already in an early stage the paper machines were driven by steam engines, the exhaust steam of which served as far as it went, to heat the drying cylinders, which simplified and cheapened the process of paper-making to such an extent that the enormously increased demand for paper of all kinds, and especially for newsprint, has since been met. The introduction of ground woodpulp gave a further tremendous impulse to the paper industry and to-day paper-making machines with a 250 *inches width of sheet* are producing newsprint at the *rate of* 1,000 *feet per minute*! It may be easily understood that these results are due to a contemporary and continuous improvement in paper-making plant and equipment allied to intensive research.

Paper Mill Machinery :—

In setting out the plant necessary for a paper mill, which is designed to produce a given quantity of finished paper, the engineer takes into consideration the class of paper to be made and the raw material to be employed. In the case of good quality writing and printings, which form the greater bulk of the paper at present manufactured in India, the equipment of an up-to-date paper mill comprises all the latest devices for the efficient handling of large quantities of raw materials, such as bamboo and/or sabai grass, chemicals, coal, etc., the economical production of steam and the generation of cheap electrical energy, together with the special machinery peculiar to the manufacture of paper.

The amount of materials to be handled may be seen from the following table, which gives *approximate* quantities for a paper production of 8,000 tons per annum of 340 working days—say, 8,000 hours.

Table showing the Materials required for Writing and Printing Papers.

Table 1.

Annual Production of Paper, say,	8,000 tons
Bamboo (All Bamboo Furnish) ..	.. 25,000 tons
Grass (All Grass Furnish) ..	.. 27,000 tons
Bamboo (50% Mixed Furnish) ..	.. 12,500 tons
Grass (50% Mixed Furnish) ..	.. 13,500 tons
Woodpulp	.. 334 tons
Rags	.. 25 tons
Country Waste Papers	.. 1,400 tons
China Clay	.. 1,080 tons
Size	.. 180 tons
Alum	.. 360 tons
Colours	.. ..
Bleaching Powder	.. 1,100 tons
Sulphate of Soda	.. 1,250 tons
Lime	.. 2,150 tons
Coal (All Purposes Fuel) ..	.. 25,000 tons
Water (Per Ton of Paper) ..	.. 50,000 gall.

In converting *Stock* into *Pulp* the various *Yields* have been definitely established by trade customs and a reference to the following table will make this clear.

Table 2.

STOCK	Yield into Pulp	Yield into Paper	Quantity in Tons	Equivalent Paper Tons
Bamboo	at 38% yield	at 80% yield.	25,000	6,080 tons
Woodpulp		at 83% ,,	334	277 tons
Rags		at 60% ,,	25	15 tons
Country Waste Papers		at 70% ,,	1,400	980 tons
China Clay		at 60% ,,	1,080	648 tons
				8,000 tons

A reference to *Table 1* will show that for a paper mill producing 8,000 tons of paper per annum, the quantity of what may be termed *imported materials* is approximately 58,000 tons. To this has to be added the product of the mill, or 8,000 tons of paper—*Table 2*—so that the total materials to be handled within the mill area is, say, 66,000 tons, or nearly 8·5 tons per ton of paper. A production of 8,000 tons per annum represents a two-machine mill—*with machines of a suitable size to present trade requirements in India*—and generally a 16,000 tons, or four-machine mill, is a better economic proposition. In the latter case the total of materials to be handled becomes 136,000 tons per annum, or something like 17 tons per hour. Transport is undoubtedly a most important factor in costs of production and requires very careful consideration. The subject is really too extensive to be dealt with, as a whole, within the confines of this paper, but in view of its importance will be referred to in general in subsequent matter pertaining to mill plant and equipment.

Steam and Power Plant :—

The economic advantages to be derived from the combined *power and process* utilisation of steam under favourable conditions common to the paper industry are now so well recognised as to need no explanation. The industry must, however, by reason of the inherent possibilities, always endeavour to keep abreast of the latest developments in the application of such a combined system.

The type of boiler unit to be employed depends mainly upon conditions obtaining and usually selects itself. For a modern pulp and paper mill, except of the smallest size, the water-tube boiler will generally be favoured, particularly, as steam pressures for economic operation of the combined power and process system are higher than one usually associates with the Lancashire boiler. The latter boiler has, of course, a wide field of operation in industrial practice, and deservedly so, being an excellent member of the steam boiler group.

The boiler house has to be regarded as the source of both power and heat, as the plant that generates steam and delivers it to the steam-using departments must be treated as a distinct

unit of the paper-making equipment. Careful consideration should be accorded to the various component parts and apparatus that form the complete boiler plant. Grate area, furnace volume, and conditions of balanced draught, must be such that combustion of the lower grade fuels is effective and complete. The conveyance and treatment of water, coal, ashes, etc., must be efficient if labour costs are to be reasonably low, transport of coal and ashes being an essential feature.

Economies in the production of steam are invariably a direct result of accurate and detailed knowledge of what is happening in the boiler house and the installation of a comprehensive metering equipment is a sound investment. Such an equipment will provide a record of plant performance and efficiencies under every-day conditions of load. Moreover, detailed and accurate recording leads to accurate costs and closer contact with the source of losses.

Investigation of the steam requirements for heating and process involves a knowledge of the quantities used in the various sections of the plant and an examination of the different apparatus, to ensure that the combined system will be employed under the most economical conditions.

The temperature of the exhaust steam is the starting point of any research into efficiency of utilisation of heat in a prime mover, and is also the starting point of a corresponding research into the efficient utilisation of this exhaust heat in a process plant.

The steam for process will normally be saturated and employed at a temperature as close to the final temperature desired as is consistent with a reasonable rate of heat transfer. The temperature, as thus determined, fixes the pressure of supply.

It is of special importance to realise the gain by reduction of pressure. The function of value in heating by this means is the *latent heat* or heat of condensation and it is interesting to compare the components of the heat contents of steam at varying *pass-out* pressures, as shewn in the following table.

Table 3.

(1) Pressure lb. ab.	(2) Heat of Condensation	(3) Total Heat	(4) Col. 2 / Col. 3	(5) Temp.
150 lb.	867·9	1198·5		358·4
125 lb.	879·4	1195·1		344·4
100 lb.	892·2	1190·7		327·9
90 lb.	898·0	1188·5		320·2
80 lb.	904·2	1186·1		311·9
70 lb.	910·9	1183·3		302·7
60 lb.	918·8	1180·1		292·6
50 lb.	926·3	1176·3		280·9
40 lb.	935·6	1171·6		267·2
30 lb.	946·7	1165·5	81·2	250·3
25 lb.	953·3	1161·7	82·1	240·1
20 lb.	961·0	1157·1	83·2	228·0
15 lb.	970·2	1151·2	84·3	213·0
10 lb.	981·9	1143·0	86·0	193·2
5 lb.	999·8	1129·8	88·5	162·3

In *power* production the steam is used as a vapour, all the advances in regard to higher pressures and superheats and lower vacua being directed towards increasing the range through which it can be expanded. The *latent* heat of evaporation, which has to be supplied in the boiler, is again rejected to the condenser, constituting a definite loss. In *heating*, exactly the opposite holds; high pressure, and especially high superheat, are in themselves of little benefit, except in so far as the temperature of the process depends on the pressure, as already mentioned.

The following tables—obtained by means of a *Mollier Diagram*—show the heat drop between various pressure limits, assuming pressures in lb. per sq. inch absolute and *saturated* steam as supply. They certainly confirm the importance of limiting back-pressures under suitable conditions.

Table 4.

Inlet Press. lb. ab.	Back-Pressure lb. ab							
	35	30	20	15	10	5	1·5	1
80	64	75	103	122	149	191	258	279
100	81	93	121	139	166	207	273	294
120	95	106	133	152	178	219	284	305
140	107	118	145	164	189	230	294	315
160	118	128	155	174	199	240	304	324
180	126	137	164	182	207	247	311	331
200	133	144	171	189	213	253	317	337
220	141	151	178	196	220	260	323	343
260	153	164	190	208	232	271	333	353
300	164	174	200	217	242	281	342	362
350	176	186	212	229	253	291	353	372
400	187	197	222	239	261	301	362	381
450	194	204	229	246	269	307	367	386
500	200	210	235	252	275	313	373	391

Table 4a.

Inlet Press. lb. ab.	Back-Pressure lb. ab.							
	150	100	90	80	70	60	50	40
80					11	23	37	54
100			9	19	29	41	55	72
120		15	24	33	43	55	69	85
140		27	36	45	56	67	80	97
160	5	39	47	57	67	78	92	108
180	16	48	57	66	76	88	101	117
200	24	57	65	73	84	95	108	124
220	32	65	72	81	91	102	115	131
260	45	77	86	94	104	115	126	142
300	57	89	96	105	115	126	139	154
350	70	101	110	118	127	138	151	166
400	81	112	120	128	137	148	161	176
450	91	122	129	138	147	158	170	185
500	98	128	136	144	153	165	177	191

CURVES OF HEAT DROP.

(From accompanying Tables 4 and 4a.)

In a paper mill requiring steam at a pressure of 100 lb. for digesters and steam at a pressure of 30 lb. for the paper-making machines, evaporators and the like, a double extraction type turbo-alternator—*see Fig. 3*—would be employed to pass-out steam at these pressures. For successful application the problem requires a thorough engineering study and costs analysis in advance. The selection of the proper initial steam pressure and superheat is vital to success and in general the balancing of steam and power demands is also of major importance. For various reasons such a balance is seldom accomplished in actual practice in combined pulp and paper mills.

The necessary water rate is the steam demand divided by the power demand :—

$$\text{W.R.} = \frac{\text{Steam in Lb. per hour.}}{\text{Load in kWh}}$$

Having determined this figure, the water rate for the turbo-alternator unit is :—

$$\text{W.R.} = \frac{\text{3412 B.T.U. per kWh}}{\text{Efficiency of unit X adiabatic heat drop}}$$

Suppose we assume an every-day working efficiency of 65 per cent, steam to electricity, and by the use of a *Mollier Diagram* determine the steam consumption for back-pressures of 1·5, 30 and 100 lb., with initial pressures up to 500 lb. and the necessary degree of superheat to give slightly superheated steam at the exhaust of the 30 lb. pass-out branch (in order to reduce heat loss in the mains to the heating system) the results are as shewn in *Fig. 4*.

While charts of this description will give results close enough for a preliminary estimate, any given case must, of course, be individually computed, based on the guaranteed steam consumption of the unit at various points of its capacity.

Preparatory Plant :—

The principal raw materials used in the manufacture of high class writing and printing papers in India are bamboo,

sabai grass, and in varying lesser quantities, imported chemical woodpulp, indigenous waste papers, rags, etc. Bamboo and sabai grass are both submitted to considerable mechanical treatment in their conversion into pulp. The treatment is somewhat similar in both cases and we shall, therefore, confine our attention to the method adopted with bamboo.

Bamboo from the forest areas is usually delivered to the mills in bundles suitable for railway transit, and in this state may be easily and expeditiously handled by means of quick travel overhead electric cranes. Other methods of transport are, of course, applicable and in general the problem of conveyance is largely determined by conditions at site. The mechanical treatment of the bamboo preliminary to digestion has been a source of considerable study and experimentation of method, none of which, so far, has been entirely successful. However, this problem, like many another in paper-making, will ultimately be solved, bamboo being still at an early stage in its commercial development within the paper industry.

Mechanical treatment is necessary in order to disintegrate the fibre and render it accessible to the chemical reagent employed in the process of digestion. Its preparation for digestion has been varied, more by reason of circumstances than requirements, but the most successful application appears to follow an attempt to combine crushing, splintering, and cutting in one process. It is a ticklish problem, as overcrushing leads to excessive waste, while on the other hand insufficient disintegration leads to excessive use of chemicals and pulp losses in the digester.

An outline drawing of one of the most successful crushing machines is shewn in *Fig. 5*.

The crusher has three pairs of rolls with different surface characteristics; the first pair breaks the bamboo into pieces about 2·5 to 3 inches long; these pieces fall by gravity to the second pair of rolls, which are below the first pair, and from the second to the third pair they are fed by a small mechanical shake conveyor. The crusher is designed to open the fibres out and represents an attempt to combine the necessary treatment in one machine. On leaving the crusher the bamboo may either be conveyed to the blower by means of a shake and screen conveyor, or by means of a simple conveyor only,

dependent upon whether screening is desired at this stage. The bamboo is thereafter discharged by pneumatic means, *via*, light section tubing and terminal cyclones and dust extraction equipment, into storage bins in the digester department; thence from these bins to the digester direct by means of special hoppers operated on a mono rail system incorporating an automatic system of weighments. Considerable scope exists for ingenuity in transport design in the departments referred to above.

Digestion of Bamboo :—

The next process in the treatment of bamboo is digestion, or the chemical process by which the various non-fibrous substances other than cellulose are dissolved, the object being the isolation of the paper-making fibre known as cellulose. The deleterious substances referred to consist mainly of starches, pectins and lignins.

The starches and pectins produce dyes which discolour the pulp, but are more soluble than lignins. Starches are soluble in water and pectins are soluble in 1 per cent caustic soda; while lignins are only soluble in 4 per cent caustic soda solution at steam pressure above 25 lb. The dye produced by the starches is not wholly washable and is not entirely discharged by excess bleaching; while the dye produced by the pectins is non-washable, unbleachable and permanent. If these dyeing reactions are allowed to take place, the most efficient bleaching results in only a cream white pulp, which requires further treatment for use in white papers by tinting, etc., all of which adds to production costs.

In a system of digestion by stages fresh liquor of a predetermined strength and at a steam pressure necessary to dissolve the lignins is applied to the fibre only *after* the starches and pectins have been disolved in liquor, which has already been employed to *break down* lignins at a previous stage of digestion. The weakest liquor is therefore applied to the fibre at the first stage of digestion, for a period of about 5 hours at a steam pressure of about 20 lb., when the more easily soluble substances are removed. The fresh liquor is then applied only at the last stage when the lignins alone remain to be treated for a short period at a steam pressure of about 80 lb. It will be seen the digestion of bamboo in stages results in economy of chemicals and steam, as higher pressure steam

is only applied at the final stage; also that the bamboo breaks down into pulp in a liquor, which is not affected by the harmful colour products of the starches and pectins.

As this is the first stage at which the application of turbine pass-out steam at the higher pressure is likely to take place, we may consider the action of the digester from the point of view of its being a steam using apparatus and in this connection an interesting point arises. The paper-maker is all against the use of superheated steam for digestion purposes and it will be remembered that in the case of the double extraction type turbine passing-out steam for process, at, say, 100 and 30 lb., provision was made for a slight degree of superheat being available at the lower pressure, it follows that a considerable degree of superheat will be contained in the steam at the higher pass-out pressure of 100 lb. Now this superheat may be retained in the steam until it reaches the digester plant—thus minimising heat loss in the steam mains—and then be de-superheated in the liquor pre-heating apparatus. This may be accomplished by the use of a modification of the present immersed coil type of heater now in vogue. If the present type of pre-heaters are jacketed and the steam space fitted with the necessary nozzles, the steam may be de-superheated as in the ordinary form of apparatus. A dual purpose may thus be served, as the result of which higher efficiencies may be obtained.

For the process of digestion a battery of digesters is invariably employed, an outline drawing of a typical unit being shewn in *Fig. 6*.

Soda Recovery :—

Before proceeding to subsequent processes in the treatment of bamboo pulp we have to consider the recovery of what is known as *spent liquors*, or waste soda lyes, which have been used in digestion. At certain stages in the digestion process these waste liquors are discharged from the digesters to large storage tanks and from these tanks supplies are drawn for use in the evaporator plant, where the first stage in recovery is effected by evaporating down the liquors to a thick syrupy mass, which can be burnt, more or less completely, into crude carbonate of soda.

For this purpose what is known as *multiple effect evaporators* are employed to concentrate the weak soda lyes to a density of from 50 deg. to 60 deg. *Twaddel*, the final evaporation and calcination of the residual mass being carried out in a rotary roaster and soda melting furnace.

The process of evaporation is as follows :—

The *spent liquor* from the storage tanks is pumped to the heating chamber of the first vessel and passed through tubes, which are heated externally by the application of steam at a pressure of 5 to 10 lb. (depending upon the degree of vacuum to be maintained in the apparatus—usually something like 5 in., 10 in., 18 in., and 25 inches, corresponding to the four vessels, or effects, in a *quadruple effect evaporator*. The steam evolved from the liquor in the *first* vessel, D_1, produced by the action of the initial steam, D_0, supplied externally, passes into the heating chamber of the *second* vessel, there in its turn produces vapour form the liquid, and is condensed, escaping at the temperature, t_{v2}, prevailing in the lower part of the liquid in that second vessel. The weight of liquid, W, which has lost the weight of water, D_1, by evaporation in the first vessel, and which, consequently, now weighs $W—D_1$, passes, at the mean temperature, t_{m1}, of the first vessel, into the *second* vessel, in which the mean temperature is only t_{m2}. Thus in cooling from t_{m1} to t_{m2} it must form steam. If C_2 be the total heat of the steam in the second vessel, then by reason of the hotter liquid entering from the first vessel

$$S_2 \quad \frac{(W-D_1)\,(t_{m1}-t_{m2})}{C_2-t_{m2}}$$

lb. of steam must be evolved.

In the *second* vessel steam is thus evolved *both* by reason of the heat of the hot liquid itself and *also* because of the steam, D_1, coming from the first vessel.

In the *third* vessel steam is produced *both* by the heat of the entering liquor $(W—D_1 — D_2)$ and *also* by reason of the heat of the steam, D_2, which is the total steam produced in the second vessel.

In the *fourth* vessel similar actions are produced, so that, in addition to the repeated action of the hot steam, there is

also the repeated action of the steam produced by the decrease in temperature in the temperature of the liquor.

As the comsumption of heating steam in the first vessel is the only steam used from an external source, we may ascertain this by the following :—

$$S = \frac{W\,(ti - tf) + X\,(Ti - ti)}{T - ti}$$

Where W = The quantity of liquor introduced.

ti = The temperature of the steam in the steam space of the vessel.

tf = The temperature of the liquor entering the vessel.

X = The quantity of water to be evaporated from the liquor in the first vessel.

Ti = Total heat in the steam evolved within the first vessel.

T = Total heat in the steam as supplied.

The process of evaporation in a quadruple effect evaporator is shewn in the *flow* diagrams *Fig. 7 and Fig. 7a.*

An outline drawing of a single unit of a multiple effect evaporator is shewn in *Fig.* 8.

The concentrated liquor from the fourth vessel, of a quadruple effect evaporator, is pumped to the rotary roaster, where actual incineration of the thick liquor takes place. The residue is discharged from the rotary roaster to the melting furnace and thence in a liquid state to the lixiviating tanks and finally extracted with hot water.

The clear solution, obtained after the impurities have been allowed to settle, is pumped to the causticising tanks where it is converted into caustic soda, the loss due to unrecovered soda being made up by the addition of ordinary commercial caustic soda.

The causticising pans are large semi-circular iron vessels into which a known volume of the recovered carbonate of soda solution is placed. A weighed quantity of ordinary quicklime is then put into a perforated iron cage, which is a fixture inside

the causticising pan at such a level that the whole of the lime is immersed in the solution. The liquor is kept in constant circulation by means of a mechanical agitator, and heated to boiling point at atmospheric pressure, with the result that, the chemical reaction sets in, the carbonate of soda being converted into caustic soda and the lime being thrown out as sludge. The saturated lime is thereafter passed through a sludge filter of the rotary vacuum type, in order to recover the soda solution still remaining in the mixture.

When the operation of causticising is completed, the clear liquor is decanted off and pumped into storage tanks, from which the necessary quantity of liquor is drawn for the digesters as required. This completes the cycle of operation in the soda recovery process. The description is necessarily all too brief for a department in which there is much to interest the chemist and the engineer, keen to utilise by-product heat and other facilities for economy of operation.

Washing and Straining :—

When the process of digestion has been completed the partially spent liquor is blown off into another digester, in readiness for use as a second stage liquor. This results in fairly good extraction of the liquor from the bamboo pulp and if necessary, a hot steam wash may be employed to further improve matters. The sodden mass of pulp is then cut out of the digester by means of a high pressure water jet, operated at a W.P. of 250 lb., and supplied by a multi-stage turbine pump of the boiler feed type. This cutting out under pressure results in the pulp being further disintegrated and opened out ; it also results in a considerable degree of washing taking place in the digester, the pulp being diluted in the process to a consistency suitable for its removal by a specially designed open type impeller centrifugal pump.

The diluted pulp is now pumped to a rotary vacuum filter, where further washing and concentration is completed. Concentration is necessary, in order to reduce the volume of bleach required at the following stage in the preparatory process.

Bleaching :—

The bamboo pulp, after washing and concentration, is bleached by means of a solution of chloride of lime. Several

methods are used for this purpose, but it is largely a question of local conditions. For the purpose in view we shall adhere to the system known as *Tower* bleaching. A battery of, say five cylindrical concrete towers, is employed, the towers being something like 14 feet in diameter and 21 feet deep with conical shaped bottoms, to facilitate the flow of pulp to the suction of the circulating pumps. Each pair of towers is connected to one centrifugal pump unit by a common "Y" pipe suction and special full bore flap type valves. The discharge pipes from the circulating pumps are connected to a common main on the top of the towers, valves and piping being so arranged that continuous circulation can be effected in series throughout the system, as a whole, or in sections, as may be convenient.

Bleach is added at the top of the first tower and the resultant mixture of pulp and bleach drawn from the bottom by the circulating pump and discharged to the top of the tower, where as it falls, it may be distributed evenly over the surface of the mixture by means of a suitable baffle-plate. A continuous and rapid circulation can thus be maintained at any section of the system, the process being very effective.

The bleached pulp is subsequently washed free from any trace of deleterious matter, as it is essential to remove all the by-products formed during the process of bleaching. These soluble by-products, if retained in the mixture, are responsible for a lowering of colour in the product.

A considerable measure of washing and straining is effected at this stage. The diluted pulp flows by gravity in a wide slow moving shallow stream over sand-tables and traps, designed to retard and collect foreign matter released by the action of the bleach. After leaving the sand-tables the pulp is passed through rotary drum type mechanical strainers, usually in series, where further impurities are removed; thence to the concentrator, where the pulp is finally washed and all traces of residual bleach eliminated. The pulp is also de-watered and thickened by the concentrator, preparatory to its being pumped to the beaters by means of special plunger stuff pumps, usually of the geared triplex ram type.

An outline drawing of a bleaching tower is shewn in *Fig. 9*.

The rotary drum type mechanical strainer, mentioned above, is an ingenious device and like other interesting equipment is, unfortunately, inadequately dealt with in a paper covering an extensive range of plant. An outline drawing of one of these strainers is shewn in *Fig. 10*.

Beating :—

The process of beating has for its object the complete breaking down of the bleached pulp to the condition of single suitable fibres. The disintegration of the fibrous material is essential for the production of a close even sheet of paper. The amount of beating required is determined by the nature of the raw material, and the class of paper to be produced. In general the quality and character of the paper made may be varied with :—

(1) The origin of the raw material.

(2) The condition of the material.

(3) The time occupied in heating.

(4) The state of the beater bars.

(5) The speed of the beater roll and its weight.

(6) The rate at which the beater roll is lowered on to the bedplate.

(7) The temperature of the contents of the beater.

It may be asserted with a great deal of truth that, of all the machines employed in the manufacture of paper from the raw material to the finished product, the beater is the most important because it is decisive for the quality of the paper. The beater is also particularly important from the point of view of power consumption, as the load in the beater house figures very largely in the power bill of the complete paper mill.

Development in the driving of beaters has followed the same course as in other industries, *i.e.*, from the purely mechanical drive, by means of line shafting to the electric group drive, and more recently to the electric individual drive, likely to be widely employed by reason of its many practical and economical advantages.

The diagram, *Fig. 11*, shows in principle the power used by a beater motor during the whole process. It will be seen that after the initial rise in power consumption during the filling-in period, the power used drops off slowly after the beating has commenced. For a given setting of the beater roll the power absorbed decreases in proportion to the progressive disintegration of the material. Having passed round the machine a number of times the beating process is so far advanced that the material flows freely beneath the roll, and the first phase of the operation is completed. The beater roll is further lowered thus reducing the space between the roll and the bed-plate, and the consequent increase in the power absorbed is reflected in the rise of the motor output, as indicated in the diagram.

The long period required to thoroughly pulp a strong material like bamboo demands a considerable amount of power. Beaters can differ considerably in their power consumption and although comparisons are made in terms of power required to beat a given weight of pulp, there are many variables present to upset results. For instance, a beater may be suitable for producing certain results, at a fairly high power consumption, whereas, another beater may consume considerably less power, but unless the same effects are obtained the comparison has little real value.

All things considered, the power required can be an interesting study indeed, particularly, where freedom of operation, as in the individual electric drive, enables the beater man to direct the beating process along any special lines conducive to raising the quality of the paper ; and also at the same time enables the engineer to secure an accurate record of the power absorbed at any stage in the process.

These advantages can lead to a saving in power costs and to a speeding up of the time required for beating. Their influence on the efficiency of the beater house should amply re-imburse the small extra outlay involved in the individual electric drive.

Operations in beating are completed by the addition to the pulp undergoing treatment of, china clay, size, and colouring materials, as required, and the resultant mixture now known as *stuff* is discharged to the stuff storage tanks. Continuous

circulation is maintained in the stuff chests by means of mechanical agitators and the mixture is now ready for the next stage in the manufacture of paper.

An outline drawing of a *Hollander* type beater, with a very good record, is shewn in *Fig. 12*.

This beating engine in its simplest form consists of an oval shaped vat, divided into two channels by a *mid-feather*, which does not, however, reach completely from one end to the other and consequently compels the pulp to flow in the manner of a continuous circular stream round the vat. In one of the channels the bed of the trough slopes up slightly to the position where the *bedplate* is fixed. The bedplate consists of a number of steel bars securely fastened into an iron frame or box, which fits into a recess placed across the channel and directly under the beater roll. The beater roll, a heavy cast-iron roll provided with projecting steel bars arranged in clumps of three (or equally spaced as circumstances demand) around the circumference, and supported on bearings at each side of the machine, revolves over the bedplate with the bars adjusted to any required distance from it, the raising or lowering of the roll for this purpose being effected by the use of adjustable bearings on a hinged movement.

The bed of the trough behind the beater roll rises sharply up from the bedplate following the contour of the roll and then falls away suddenly, thus forming what is known as a *backfall*. When the beater is in operation, the mixture of water and pulp is drawn between the roll and the bedplate and circulated round the vat. The material is disintegrated to the required degree of fibrillation and *wetness* for the production of a particular grade of paper and thereafter discharged to the machine stuff chests.

The Paper-making Machine :—

We have now reached a stage in the manufacturing process where the formation of paper in the web commences and is finally completed after a series of operations on the paper-making machine. The integral power and drying sections of each machine are in principle very similar, but in order to produce the many different qualities of paper they vary greatly in size and equipment. For instance, they may be capable of producing the finest papers at the rate of, say, 20 ft. per minute, or they

may be capable of producing newsprint 250 inches in width at the rate of 1,000 ft. per minute. We propose, however, to deal with machines capable of making fine quality papers at a rate of from, say, 20 ft. to 250 ft. per minute, with a width of, say, 120 inches.

The *wet* end of the paper-making machine, ranging from the mixing box and sand-tables to the last stack of press rolls, has, from time to time, received a great deal of attention. This has resulted in improvements being gradually evolved through close co-operation between the practical paper-maker and the engineer.

The first part of the wet end equipment is the stuff box, water box, and sand-tables. The stuff, which has been delivered from the beaters to the machine stuff chests, is now pumped to the stuff box, or what is generally known as the mixing box, where the stuff and water is carefully mixed to ensure that a strictly steady head is maintained, as a small variation will appreciably effect the flow of stuff from the gate. Thence to the sand-tables, which, as the name implies, are essentially for the purpose of retaining particles of grit and sand, and other foreign material of a high specific gravity which settle from the diluted pulp. The design and construction of the sand-tables has to be such that a sufficient but steady flow can be maintained to allow these coarse particles to settle out, while at the same time mildly agitating the fibres and other paper-making susbtances to ensure even blending. This has to be accomplished without undue frothing, which is a source of dirt and inconvenience.

From the sand-tables the stuff flows by gravity to the strainers, whose function is to screen the pulp and prevent the passage of anything coarser than the fibres. Sufficient straining or screening capacity must be provided, otherwise the consequent forcing of stuff through the slots will lead to inefficiency. The actual size of the slots must be governed by the class of furnish to be used, and knots of stuff, unbeaten fibres and other objectionable matter should be allowed to settle, preparatory to being drawn off to the auxiliary strainer, where further screening of the refuse takes place, the recovered pulp being returned to the system. From the strainers the stuff

passes by gravity flow to the head, or flow box, and has now reached the first part of the actual paper-making machine.

The flow box has to be designed in such a manner that it will deliver the entire flow of water and pulp mixture from the strainers on to the wire in an intimately mixed state. Provision must be made for fine control so that there are no undue eddies or currents, the stuff flowing evenly over the apron and under the slice to be delivered on to the wire at a speed consistent with that of the wire. The stuff is carried forward on the wire and quickly forms into a wet web of paper, the water falling through the meshes of the wire, being recovered and pumped back to the mixing box.

The problem of paper formation is to project the stuff on the wire in such a way that the fibres shall be intimately mixed and crossed in a level layer, and the bulk of the capillary water drained off by gravity before the fibres have time to straighten out in the direction of the machine. To assist in this felting of fibres and formation of the sheet on the wire, the wire frame is mounted on hinged pivots and an oscillatory movement is set up by the action of what is known as a *shake motion.* This latter mechanism is designed to work equally well at all machine speeds and the strokes can be varied from zero to 1 inch in length and up to a rate of 1,000 strokes per minute, corresponding to a slow speed stroke and high speed tremor. It may be remarked that when making fine quality papers it is essential that the fibres get time to settle down on the wire, in order to obtain an absolutely flat and close sheet, and this means a long wire.

To return to the process, the wet sheet has now been formed and further water is extracted as the wire conveys the web over the suction boxes, which are operated under conditions of low vacuum, thence under the couch to the press rolls, where the remaining water is partially squeezed out and the sheet now considerably strengthened passes from the press rolls and enters the machine drying section. An important point to be remembered at this stage is that insufficient press rolls, or inefficiency of operation of those installed, will lead to excessive moisture in the sheet going forward to the drying cylinders.

Machine Drying of Paper :—

The drying effect in a paper-making machine is produced by the transfer of heat through the shell of the cylindrical dryers from the heat given off by the steam within, which in some cases is supplied by the exhaust steam from the engine driving the paper-making machine. The heat is transferred to the sheet, which is held in contact, by means of felts, with the external surface of the cylinders driving out the moisture in the sheet. Water and air must be eliminated from the cylinders if maximum efficiency and drying capacity are to be secured, for the cylinder is naturally most effective when in active circulation. The elimination of water and air from paper machine cylinders is, and always has been, a constant problem which paper mills have to face. The problem is further complicated by the fact that steam has to be used economically.

It has been found, by numerous tests on fine quality papers, that about three pounds of steam are required to dry one pound of paper in actual practice. The theoretical quantity may be determined by the following formulae :—

$$S = \frac{X\,(T-ti) + ws\,(tf-ti)}{Ti-tf}$$

Where S = Lb. of steam required.

X = Weight of water in lb. which has to be evaporated for each ton of air-dry paper made.

W = Weight of air-dry cellulose (2,240 lb).

s = Specific heat of air-dry cellulose.

ti = The initial temperature of pulp and water running on the wire.

tf = The final or maximum temperature to which the paper is heated on the drying cylinders.

T = The total heat units contained in one lb. of steam at 212 degs. F. under atmospheric pressure.

Ti = The total heat units contained in one lb. of steam at the pressure prevailing within the drying cylinders.

X is ascertained by estimating the water in the paper after passing the press rolls, and again after having passed over the drying cylinders.

This may be calculated as follows :—

$$W = \frac{M_1 - M}{100 - M_1}, \text{ where}$$

W Lb. water evaporated per lb. dried paper.
M_1 Percentage of moisture in sheet entering dryers.
M Percentage of moisture in dried sheet.

As for example, paper entering 30 per cent dry equals 70 per cent moisture. Paper leaving equals 6 per cent moisture. By substitution we have :—

$$\frac{70 - 6}{100 - 70} = 2{\cdot}14 \text{ lb. water evaporated per lb. paper.}$$

The actual steam consumption per lb. of paper obtained on a test as conditions above was 3·134 lb. as compared with the calculated figure of 2·621 lb., or an efficiency of 83 per cent, which is a reasonable figure for slow running machines. The balance of 17 per cent represents loss of heat by radiation, moisture in steam, etc.

The sheet of paper having passed through the drying section of the machine is now ready for glazing, or *machine finishing*, a process which turns the dull rough surface of the paper into a highly polished smooth surface fit for general use. This treatment consists in passing the web of paper between steam heated rolls under heavy pressure, the pressure being applied by means of compound levers and weights. The rolls are arranged one above the other in stacks of five, seven, or more, as the case may be and are known as *calenders*.

This operation effects many changes in the paper, besides imparting a good finish. The thickness of the sheet is reduced, due to the fibres being compressed much closer together, the tensile strength of the paper is also materially increased and in

every way the paper is improved. Machine finish has, however, to be done in moderation, as excess glazing weakens the paper and lessens its folding capacity.

On leaving the calenders the finished web of paper is reeled into rolls of a suitable size for passing to the paper cutting machines. During the formation of the rolls the web advance is constant and the peripheral speed of the roll, which increases in diameter, must, therefore, also be constant, the number of revolutions the roll of paper makes per minute will necessarily have to decrease gradually in the same degree as the roll increases in size. To make the speed of the roll winder adapt itself automatically to these conditions a friction clutch is inserted between the spindle of the roll and the drive.

This completes the process on the paper-making machine, but before proceeding to the next and final stage in dealing with the product we must consider the paper-making machine drives, which are a feature of considerable mechanical interest.

The Paper-making Machine Drive :—

The drive of the paper-making machine has developed on somewhat similar lines to that followed in most industries. Firstly, we have the simple slow speed direct drive horizontal single cylinder engine, with its limited variation in speed control and the paper machine speed ratio obtained by means of straight gears, or *speed wheels* (necessitating a shut-down and change of speed wheels to alter the machine speed beyond the very limited range provided by the engine governor) driving intermediate shafting and bevel gearing to the machine sectional drives ; the latter consisting of long lines of belting on flat faced pulleys, each section controlled by claw type clutches, but with no adequate provision for sectional variation of speed other than the primitive method of sticking pieces of felt on the pulley face, as make-up to allow for *draw* or tension on the paper. It is interesting to note that paper-making machine drives of this description have been in existence in India for over fifty years and are still in operation.

Secondly, we have the high speed driving gear incorporating the totally enclosed high speed vertical type compound engine, with its variable speed control over a wide range in

paper-making machine speeds. The drive consists of sections made up of an overhead shaft carrying a conical belt pulley driving downwards to a bottom pulley. This bottom pulley is carried on a shaft supported in bearings on a swing cradle frame. This cradle and the shaft are lowered by crank movement from the front side of the machine for starting up. When a section is to be stopped, the cradle is raised through the crank and the driving belt between the top and bottom cone is released and runs loosely over the top pulley. The top shafts are driven by rope pulleys from the two high shafts driving fore and aft through two endless ropes, each provided with a stenting device. The rope speed is reduced through machine-cut spur reduction gears with pinions of special metal. The sectional driving shafts to connect the rolls or dryers are supported on special stool frames with compensated adjustment, couplings of claw type being provided on each roll end. Screw type belt-shifters are provided on each section for the accurate adjustment of the belt on the surface of the pulley to regulate the *draw* or tension required in forming the sheet. This drive and equipment has given excellent service in the paper industry and is used in India at the present time.

Thirdly, we have the enclosed sectional drive incorporating the high speed engine, as before, or the variable speed electric motor. The gear units are driven from a continuous overhead main line shaft, the whole equipment being an excellent example of a modern high efficiency drive.

In each case the auxiliary plant of the paper-making machine, pumps, agitators, etc., may be worked from lines of shafting driven by separate constant speed electric motors, or individual drives may be installed.

Calendering, Cutting, Slitting and Re-winding :—

The machine-made rolls of paper from the paper-making machine are transported by overhead runway to the calendering, cutting, slitting and re-winding machines. For high class papers the web of paper is subjected to further treatment to improve its surface beyond that of the machine finish already imparted. As in the case of machine finish, the treatment consists in calendering or passing the web of paper between steam heated rolls, or cylinders under heavy pressure, the rolls being arranged

one above the other. As a rule the top and bottom rolls are of chilled iron, whereas, the intermediate rolls consist alternatively of chilled iron and of cotton. The calender is usually driven on the third roll from the bottom and this roll does not run at more than 100 to 120 revolutions per minute, according to the speed at which the calender is to work. Belt transmissions are usually employed, direct coupled slow running electric motors being far too expensive.

All kinds of paper cannot be calendered at the same speed. For each kind of paper there is a calendering speed, found by experience, which gives maximum results. To obtain the highest efficiency of the calender it is essential that the drive should be variable. As a rule, a speed range of 20 to 30 per cent is sufficient, although fine printings may require wider ranges of about 1 to 2 to 1 to 3. The operating speed is anything from 200 to 500 feet per minute, and when commencing work, it would be impossible to pass the beginning of the paper web smoothly and safely between the rolls at such a high speed. For *threading* in the paper the speed required is from 25 to 40 feet per minute, so that the speed of the drive must be capable of being varied according to normal working conditions, and also of being reduced to the low speed for threading in the paper. Compared with the indirect mechanical drive, a properly designed electric drive for the calender presents considerable advantages in the operation of the unit as a whole.

The drive for the paper cutters presents little difficulty and is easily met by a constant speed electric motor.

The roll slitting and re-winding machines serve to wind the web delivered by the paper-making machine, into narrower and very tight well wound rolls suitable for printer's use. The re-winder consists in principle of two shafts, the one holding the paper roll as it comes from the paper-making machine and the other being the one on which the paper is to be re-wound as it is unwound from the first roll. The reason for re-winding the paper in this manner is to obtain a continuous and faultless web containing many thousands of feet without a break.

The re-wound paper rolls are formed side by side on a single shaft, and during the winding process the rolls are in peripheral contact with two revolving rollers by which they are

driven. With this method of drive, the turning moment of the roll slitting machine does not depend upon the diameter of the roll being wound, and it follows that if the driving speed is constant, the paper speed will also be constant, whatever the diameter of the roll. It can be said that operating conditions can be met entirely by the use of variable speed electric motors.

This completes the general reference to machinery and plant within the paper mill.

It will perhaps add to the general interest of such descriptive matter if we refer, by means of the chart shown in *Fig. 13*, to the relationship of the cumulative costs per ton of paper produced by a plant such as that described in this paper.

The further diagram, shown in *Fig. 14*, is deduced from that of *Fig. 13*.

Conclusion :—

The purpose of this paper will be served if it puts before other engineers a branch of engineering different in many respects to that of their own. The limits of a paper do not permit of an adequate reference to sections of plant and equipment, which are of considerable interest in themselves, but this is unavoidable in dealing with a comprehensive subject.

The paper industry in India, although long established, is as yet on the threshold of a future that is likely to be of great commercial importance to the country and in the development of which engineers can play an important part.

In looking to the future the following facts are outstanding : India is one of the poorest consumers of paper in the world. For instance, the consumption per head of the population in Britain is stated to be nearly 100 lb. Whereas, in India, with a population of 350 crores, it is still less than 1·15 lb. per head. Making all due allowances the industry is undoubtedly open to considerable development.

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TENTATIVE HYPOTHESIS ON THE NATURE OF FRICTION WITH ITS BEARING ON ENGINEERING QUESTIONS INCLUDING FLOW OF WATER

BY

S. B. JOSHI AND R. N. JOSHI
ASSOCIATE MEMBERS.

Hypothesis :—(1) Introduction (2) Present position and confusion as regards 'Friction Laws' (3) Statement of our Hypothesis ; Equation of friction (4) Two paradoxical laws of solid and fluid friction explained (5) Co-efficient of friction. **Applications :**—(6) Lubrication (7) Smoothening of surfaces (8) Kinetic and rolling friction. **Flow of Water :**—(9) Critical velocity (10) Resistances to flow of water ; Peripherial shearing, Viscous Resistance, and Impact Resistance causing eddies (11) Derivation of the formula for velocity of the flow of water (12) Comparison with Chezy and other formulae (13) Conclusion.

1. HYPOTHESIS.

(i) Introduction :—We have attempted in this paper to frame an 'Hypothesis on the nature of friction' which, it is hoped, will be of much use to every one engaged in Engineering research. It is an attempt to find a way out of the present confusion of thought about the 'Phenomenon of Friction', with which every Engineer is vitally concerned.

(ii) Present Position :—Results of the Phenomenon of friction are presented by the so called 'Laws of Friction.' Laws of solid friction are :—(1) Frictional resistance is proportional to the normal pressure. (2) It is independent of the area in contact. (3) Static friction is greater than kinetic friction. Laws of fluid friction are :—(1) Frictional resistance is independent of the fluid pressure. (2) It varies directly with

the area of contact. (3) It is proportional to the N-th power of the relative velocity, where N is equal to 1 for very small velocities, but for velocities which occur in actual practice N varies from 1·7 to 2·2 and has an average value of 2.

These laws are said to be true within certain limits and 'beyond these limits the laws stated are certainly incorrect and are to be regarded as mere practical rules of extensive application certainly, but without any pretension to be looked at as really general rules.' A study of the results of various experiments carried out to study the subject of friction conclusively demonstrates the existing confusion of thought and our total ignorance regarding the nature of friction.

It is curious to note how the same Phenomenon of friction should present apparently paradoxical results in case of Solid Friction and Fluid Friction. Solid Friction is proportional to normal pressure while Fluid Friction is independent of it. Solid Friction is independent of area, while Fluid Friction is directly proportional to area of contact. The difficulty is more obvious when we try to infer from these laws the behaviour of Friction in case of surfaces which are neither perfect solids nor perfect liquids. We know that there is no hard and fast line of distinction between the two states of matter.

The confusion is certainly due to 'Imperfect knowledge of the molecular and the molar actions which take place at the surface of separation of solid bodies in contact.' The nature of the surface action is still obscure and the so-called Laws of Solid Friction are largely empirical.

We do not propose to hypothesize on the constitution of matter as such. Ours is a mechanical hypothesis giving rational explanation of the Phenomenon of friction and putting most of the well-known results of friction in a logical sequence. It is as such of greater interest to an Engineer than to a Physicist.

(iii) Our Hypothesis and the Equation of Friction:— The smoothest surfaces that we get in practice are microscopically rough or irregular. In case of even surfaces the irregularity is more or less regular. Roughness of a surface is made

up of (1) Its molecular roughness or irregularity depending upon the molecular build of the material and (2) Physical roughness of the surface.

In any such position as shown in FIG. 1, the upper body is supported by the lower one at various contact points. The number of contact points and the reactions at each of them depend upon the particular relative position of the bodies. If now a pull 'P' is applied, the upper body has a tendency to move forward and this tendency is checked by obstacles. Taking first the case of a single obstacle say A_1A_2, it can be easily seen that the obstacle can be overcome either by (1) A_2 passing over A_1 or (2) shearing the obstacle A_1 or (3) shearing the obstacle A_2.

The force required for A_2 to pass over A_1 is given by $\triangle P = \triangle W.\mathrm{TAN}\varphi$, where $\triangle P$ = Force, $\triangle W$ = Weight supported at a single contact point and φ = Effective angle of inclination of the ascent with the direction of force.

If shearing of the obstacles, either A_1 or A_2, is to take place, it will be along the surface of least resistance and supposing the material of each body to be homogeneous, shearing will take place along the plane parallel to the direction of force, that is, the areas of shear will be enclosed by the contour of the obstacles at the level of the point of contact. Thus the force required for shearing A_1 or A_2 will be $S_1\triangle A_1$ or $S_2\triangle A_2$ where $\triangle A_1$ and $\triangle A_2$ are the areas under shear and S_1 and S_2 are the breaking shear stresses of the two bodies at the planes of separation.

Now in any position there are various points of contact say 'N' and every one of the obstacles can only be overcome in one of the three ways mentioned above. Therefore the number of ways in which the 'N' obstacles can be overcome is 3^N; and they are actually overcome by that particular combination for which the integral resistance is the least. At every instant the whole situation is changed, a new set of obstacles is created and the combination of the 'Least Integral Resistance' is automatically calculated and executed in that small instant. Leaving all complexities to themselves the above facts can be gathered in the 'General Equation of Friction' $P=f(W)+f(N_1, N_2, A)$ that is Friction = Pressure Friction + Shear Friction, where P = Frictional resistance, W= Normal pressure. N_1 and N_2 are the shear elasticities of A_1 and A_2, and A= Area of contact.

The least integral resistance for successive combinations will not exactly be the same for surfaces met with in practice. The frictional resistance slightly varies from moment to moment during the progress of motion. This is confirmed by experience.

(iv) Our Hypothesis and the two Paradoxical Laws of Solid and Fluid Friction :—In the case of solid friction, the shear elasticities of the materials are so high that little chance is left for the obstacles to be sheared off; and most of the obstacles have reluctantly to be overcome by passing over, that is, by over-riding. In the equation of friction $P = f(W) + f(N_1, N_2, A)$, the latter part or shear friction is mostly negligible. Hence it is that in case of solids, friction is directly proportional to normal pressure.

But this is true only for small loads. If the load increases to such an extent as to make it easier to shear off some of the obstacles than to over-ride them, then the co-efficient of friction will not remain constant but will decrease with the increase of pressure. This deduction from our Hypothesis is confirmed by experimental results. 'Experiments by Ernest Wilson show in general that co-efficients decrease with the intensity of pressure' "heavier the wheel loads the less the resistance per ton. The resistance of an empty standard gauge car weighing about 17 tons is about 8 lb./ ton on good track and for a loaded car weighing 60 to 70 tons, about 4 lb. ton or even less on good track."

The law that solid friction is independent of the area in contact is an obvious corollary; for greater the number of contact points, less is the weight supported at each contact point, so that the value of $\Sigma\,(\triangle W.\ \mathrm{TAN}\ \varphi)$ remains the same and is independent of the number of contact points, that is, independent of area. It should be noted that the value of work done in motion by pressure friction $f\,(W)$, that is, by $\Sigma(\triangle W.\ \mathrm{TAN}\ \varphi)$ is nothing more than the work required to be done in raising the centre of gravity of the upper body through a height sufficient to overcome the obstacles.

In the case of solid liquid friction on the other hand shear elasticity of the liquid is extremely small (a perfect liquid is that which offers no resistance to shear). All the obstacles

(most of them) are removed by shearing the liquid. In the equation of friction $P = f(W) + f(N_1, N_2, A)$, the portion $f(W)$, the pressure friction is mostly negligible and the frictional resistance depends upon the area of contact and is independent of normal pressure.

(v) Co-efficient of Solid Friction :—When the obstacles are overcome by passing over, the frictional resistance is f (W), that is, Σ ($\triangle$W. TAN φ) where φ is the angle of average inclination and TAN φ u. In practice we know that u $<$ 1, that is, TAN $\varphi <$ 1. This leads us to a guess that all solids with very high shear elasticities have an angle of average inclination $< 45^\circ$ and that higher the value of the angle of average inclination above 45°, less is the shear elasticity of the body, so that shearing is preferable to passing over. Presumably bodies with an angle of average inclination of about 90° offer absolutely no resistance to shear (perfect liquids).

Here we have departed from our professed intention not to touch the subject of the constitution of matter; but we might note in passing that we do feel that it will not be impossible to translate our Hypothesis in the new light of modern theories of matter.

Reference to other laws of friction will be found under applications.

II. APPLICATIONS.

(vi) Lubrication :—It is customary to explain the effects of lubrication by saying that a thin film of the lubricant is interposed between the rubbing surfaces with the result that frictional resistance is wholly of the nature of fluid friction.

This suggests as if friction between two lubricated bodies A and B (FIG. 2) is the limiting case of the two bodies A and B moving independently in the fluid L, the distance 'X' between them tending to Zero. If this were to be so, P (Friction between lubricated bodies) = Pal (friction between A and L) + Pll (internal friction in the lubricant) + Plb (Friction between L and B). This means P must follow the laws of fluid friction and consequently must be independent of normal pressure.

But the frictional resistance between two solids A and B however lubricated, must depend upon the normal pressure, although the lubricant reduces the resistance considerably. This shows that friction between two lubricated bodies is not at least wholly fluid friction. Moreover as fluid friction depends upon the shear elasticity of the fluid, on the basis of fluid friction theory for lubrication, the least viscous lubricants like air and water would have been the best.

It is clear that the action of lubricants does require some better rational explanation.

On the basis of our Hypothesis the action remains essentially the same, whether the interspaces between the irregularities are filled in with (1) air or (2) a special lubricant ; and our general equation of friction holds good.

Refer to FIG. 3. The interspaces are filled with a special lubricant. (1) Viscosity of the lubricant makes it more capable of confinement. (2) Volume elasticity of the lubricant produces pressure in all directions with small volumetric strain. (3) We surmise, surface tension adds to the quality of the lubricant—in probably helping to keep its film intact ; but we cannot say anything definite for the present.

Now when a pull P is applied, the lubricant in the interspaces gets very slightly compressed and produces pressure in all directions. The result is that a portion of the normal pressure between the solid bodies is counter-balanced by the compressed lubricant ; and the effective normal pressure at those contact points, where the process of overriding the obstacles is going to take place, is considerably reduced. Therefore in the General Equation of Friction $P = f(W) + f(N_1, N_2, A)$, $f(W)$ is considerably reduced and corresponding to this reduction, the slight increase in $f(N_1, N_2, A)$ due to shearing of the lubricant is negligible.

Water and Air, if it is possible to properly confine them, should act as good lubricants.

(vii) Smoothening as a Result of Friction :— In FIG. 1, before A_2 overrides A_1, the latter is slightly shear-strained and again comes to its original position after A_2 has

passed over. A constant repetition of the shear straining effect as above, and sometimes accentuated by to and fro motions causes fatigue in the material and weakens the cohesion of A_1 with the main body. Under such circumstances A_2 sometimes finds it easier to shear off A_1 than to override it. This causes the smoothening of surfaces. This will also explain how frictional resistance is found to be diminished (1) after the rubbing process has continued for sometime and (2) at very high velocities.

(viii) Kinetic and Rolling Friction :—(a) *Static and kinetic friction*—It is well-known that static friction is greater than kinetic friction. There are experimenters who say otherwise ; but we might dismiss their findings as due to errors of observations (Kimball's experiments show that kinetic co-efficient may be greater than the static).

When a body starts sliding, work done on it in raising its contact points over the obstacles is stored in it, as potential energy, and the same, in the forward path of the body and the downward path of the contact points, is converted into kinetic energy. The part of this kinetic energy goes to help the moving body in passing over or shearing off the next series of obstacles. Resistance to motion during movement is therefore less than that in the beginning when no help of this sort is available.

The remaining part of the kinetic energy is spent in the production of heat, known as the 'Heat of Friction' during collisions of obstacles.

It should be noted here, that if there were 'No Friction' at all, bodies moving with uniform velocity in a straight line, would continue to do so without requiring any propelling force. But even with the 'No Friction' condition, force is required to bring into motion any body which is at rest according to Newton's first law. This also partially accounts for the excess of static friction over kinetic friction.

(b) *Rolling Friction*—In the case of rolling, irregularities of the surfaces engage one another and during rolling the centre of gravity of the rolling body is not required to be raised to the same extent to which it would be raised during sliding. Taking the extreme case of a body A which quite fits into the

irregularities of B (FIG. 4) it can be seen that A can move forward without its centre of gravity being raised at all. If in this case A is to slide on B much friction will be caused. Thus rolling helps to lessen f (W) and hence to reduce the total frictional resistance.

III. FLOW OF WATER.

It will be interesting to study the different characteristics of the flow of water in the light of our hypothesis. There is one essential difference between the motions of solids and liquids. In case of solids, the motion of any three points in the solid (not in the same straight line) determine the motion of the whole solid. In case of liquids, individual particles, constituting the liquid have got greater freedom of motion in relation to the whole mass of the liquid. This accounts for the influence of velocity on resistance to motion of liquids.

(ix) Critical Velocity :—Water can keep a continuous uniform stream line motion till a limit of its cohesive stresses is reached. Thereafter the motion is unsteady or sinuous.

In order to visualize the exact nature of the phenomenon of critical velocity we give, in FIG. 5, three diagrams depicting the conditions of the flow of water giving rise to sub-critical and ultra-critical velocities. Particles of water after passing over the obstacles are projected forward and after describing the projectile parabolic path reach the solid surface (1) either before the centre of the trough, (2) at the centre of the trough or (3) beyond the centre of the trough.

In the third case, the particles will dash against the facing incline of the next obstacle and will be reflected back. Both the horizontal and the vertical components of the velocity of the reflected particle tend to cause turbulence and eddy currents and the whole of the kinetic energy of this particle is absorbed in the process. This velocity is then the ultra-critical velocity, usually met with in practice.

When the particle reaches the solid, before the centre of the trough, any of its further reflections have no components to oppose motion, that is, to form turbulence or eddies. This velocity is sub-critical velocity. The kinetic energy of the particle is not lost in this case.

The distinction—that, in case of ultra-critical velocities, the kinetic energy of the perimetrical particles is absorbed in causing turbulence while in case of sub-critical velocities the energy is not lost—is worthy of note. It makes all the difference between the condition of the flow of water at velocities above and below the critical velocity.

It should be noted that all the above discussion applies *mutatis mutandis* to a solid moving in a liquid. The obstacles in the solid surface dash against the confined portion of the liquid which (when the velocities are above the critical velocity) not getting sufficient time and space for release, gets compressed. The stresses consequent upon these compressive strains constantly act against the motion of the solid.

(x) Resistance to Flow of Water :— Resistance to flow of water consists of three different classes :

(1) Work done in shearing the perimetrical mass of the liquid, that is the factor $f(N_1, N_2, A)$ in our Equation of Friction.

In case of perfect fluids this will be zero. But we do not meet with perfect fluids in practice and practically all liquids offer more or less resistance to shear. Refer FIG. 6.

Let

δl = length of an elemental strip ABCD of channel.
B = Wetted perimeter.
φ = Angle of average inclination of the obstacles constituting the roughness of the surface.
fs = Maximum shear stress of the liquid.
N = Shear elasticity of the liquid.

Let a mass of water ABCD move to CDEF—a distance of 'dl'

Volume of liquid sheared

$$= \frac{B \times \delta l \, \text{TAN}\varphi \times \delta l}{3}$$

$$\text{Work done in shearing} = \text{shear resilience} = \frac{fs^2 \times \text{Volume}}{2N}$$

$$= \frac{B \times \delta l \, \text{TAN}\varphi \times \delta l \times fs^2}{3 \times 2N}$$

(2) Some work will be done in overcoming the viscous resistance to the shear of adjacent parallel planes. As viscous resistances vary with the first power of the velocity, let the work done be $KA\delta lV \times \delta l$ where, A=Cross-Section of the Channel, V=Velocity.

This has no reference to our Hypothesis, which does not deal with the internal resistance of the fluids.

(3) Impact resistances, giving rise to turbulence. When the velocities are above the critical, there is a further factor resisting the flow of water. It has been shown above that, for velocities above the critical, the kinetic energy of the mass of water equal in volume to that sheared along the perimeter constantly gets absorbed in causing turbulence. Work done by this mass of water, causing turbulence, for a strip of length δl and moving through a distance δl, (Refer FIG. 6) is

$$=\frac{MV^2}{2g}=\frac{\text{Volume}\times V^2}{2g}$$

where W is the weight of unit volume of the liquid. Work

$$\text{done}=\frac{B\times\delta l \text{ TAN } \varphi \times\delta l\times W\times V^2}{3\times 2g}$$

(xi) **Derivation of the Formula for the Velocity of the Flow of Water :**—On the basis of the above expressions for resistances, we shall now derive an expression for the velocity of flow. Refer FIG. 6.

Let a mass of water ABCD of cross-section A, and length δl move from ABCD to CDEF, a distance of δl.

Let P be the pressure on AB and $(P-\delta P)$ that on CD.

Therefore, propelling force is $\delta P\times A$. And the work done by the propelling force is $\delta P\times A\times\delta l$.

As the velocity of water is uniform, that is, there is no acceleration ($\frac{dV}{dT}=O$) the work done by the propelling force must be equal to the resistances.

Work done by the propelling force=Energy spent in (1) Shear along perimeter + (2) Viscosity friction (Internal resistance) + (3) Impact Friction causing turbulence.

$$\delta P \times A \times \delta l = \frac{B \times \delta l \mathrm{TAN}\varphi \times \delta l \times fs^2}{3 \times 2N} + \frac{KA\delta lV \times \delta l}{1}$$

$$+ \frac{B \times \delta l \mathrm{TAN}\varphi \times \delta l \times W \times V^2}{3 \times 2g}$$

Dividing both sides by the mass $A\delta lW$ of the strip ABCD of water,

$$\frac{\delta P}{W} = \frac{\mathrm{TAN}\varphi \times fs^2}{6NW} \times \frac{B\delta l}{A} + \frac{K\delta lV}{W} + \frac{\mathrm{TAN}\varphi}{6g} \times \frac{B\delta lV^2}{A}$$

But $\frac{\delta P}{W}$ is the head lost say δh.

$$\therefore \quad \delta h = C_1 \frac{B\delta l}{A} + C_2 V\delta l + C_3 \frac{BV^2\delta l}{A}.$$

$$\therefore \quad \frac{\delta h}{\delta l} = C_1 \frac{B}{A} + C_2.V + C_3.\frac{BV^2}{A}.$$

But, $\frac{\delta h}{\delta l}$ = Slope S, and $\frac{A}{B}$ = Hydraulic Mean Depth = R.

$$\therefore \quad S = \frac{C_1}{R} + C_2V + \frac{C_3V^2}{R}.$$

$$\therefore \quad C_3V^2 + C_2RV + (C_1 - RS) = O$$

Solving the quadratic we get,

$$V = \frac{-C_2R + \sqrt{C_2^2R^2 - 4C_1C_3 + 4C_3RS}}{2C_3}$$

(xii) Comparison with other Formulae :— Our formula for velocity tallies with the famous Chezy formula $V = C\sqrt{RS}$, when effects of resistance to shearing along the perimeter and of the viscous resistances in the whole mass are neglected. This affords a confirmation for the correctness of the skeleton of the Chezy formula within its limits ; and conversely our Hypothesis gets a strong support by the fact that the skeleton of the formula which has stood the test of time can be derived independently on the basis of our Hypothesis.

It must be noted that the formula for velocity in Art. 11, is not applicable below the critical velocity, because impact resistances causing eddies are completely absent for velocities below the critical velocity, as has been explained before.

The Chezy formula and all other formulae are purely empirical; on the other hand the above formula in Art. 11 is based upon abstract deductions on the basis of our Hypothesis. The derivation of the skeleton of the formula for V on the basis of our Hypothesis throws quite a new light on the phenomenon of the flow of water. Quantity of water for a certain thickness along the perimeter (depending upon the physical and the molecular build of the surface) constantly loses its kinetic energy causing turbulence in the mass of water. Greater the remaining mass of water, less is the total effect of the turbulence. That is why the term $\frac{A}{B} = R$, Hydraulic mean radius, automatically comes in the equation for velocity.

We do feel that viscous resistance in the mass of the liquid, surface tension and such other factors play a great part in determining the velocity of flow. We do not dilate on that question as it is not the main theme of this paper. That will probably further modify the equation for velocity, especially, at velocities lower than the critical velocity.

(xiii) Conclusion :—Our Hypothesis gives a ready explanation of most of the existing phenomena of friction and can safely be used as a means for the orientation of the existing empirical formulae on a rational basis. Whole of the above discussion is qualitative; no attempt is made at any quantitative investigation, as any such attempt is premature without getting the qualitative aspect of the question thoroughly ventilated by a free discussion amongst Engineers.

LACEY'S THEORY AND DECCAN CANALS

BY

RAO SAHEB N. S. JOSHI, Member.

PART I

The design of Irrigation Canals in the Bombay Deccan, and other similar tracts of igneous formation is a problem which has not received as careful attention from Engineers as it really deserves. In the past, the section of every individual canal in the Deccan has been determined by its designers by local considerations and personal judgments. No attempts to base broad rules for designs of different channels on careful considerations of economy appear to have been made. The only formulae used are those of the type of Kutter's and Bazin's formulae which lay no restrictions on the bedfall or the width-to-depth ratio of channels. It may be that Engineers did not then see any definite advantage in having channels designed according to a certain set of rules fixing the bedfall and the width-to-depth ratio.

2. This problem however needs study on broader lines. This subject has two branches :—

(1) Economy in the cost of first construction.

(2) Difficulties in maintenance such as silting, scouring, etc.

To give an example from channels in alluvial tracts, it is shown theoretically that a semicircular shape gives the most efficient channel, as the Hydraulic Mean Depth is the minimum; a semicircular shape can therefore be said to be the most economical as regards (1) above. However, practical experience shows that all large canals have to be wider and shallower than a semicircle. Kennedy's formulae laid down certain rules in this direction. As said above, a similar detailed study of economical designs of canals in non-alluvial tracts like the Bombay Deccan has not unfortunately been made in the past. Similarly a systematic study on difficulties in maintenance

such as scouring or silting has also not been made. There have, however, been some Engineers who believed that Kennedy's theory and perhaps his formulae (with certain modifications) applied to non-alluvial tracts as well. No strong case advocating the use of Kennedy's theory to Deccan has however been made out and hence no important discussion as to the applicability or otherwise of that theory to the said tracts has been on record in Engineering publications. However, Kennedy's formulae have been mentioned or used though in a restricted sense even in the designs of certain canals in the Deccan. There was but little following to this method.

3. Of late, the theory of the designs of channels in alluvial tracts has received very serious attention of Irrigation Engineers. The latest theory is that by Mr. Gerald Lacey. As in the case of the Kennedy theory there has been no definite attempt to show that Lacey's formulae and theory are applicable to Deccan and similar other tracts. Mr. Lacey has not expressed his views about Deccan in particular but has made himself amply clear by stating that his theory and formula applied to channels flowing in incoherent silt conveyed by themselves. However there are Engineers who believe that Lacey's theory applies to Deccan at least to a limited extent. In fact certain channels in Deccan have recently been designed on Lacey's theory. But no one has as yet publicly advocated or repudiated this theory as applied to Deccan canals.

4. In fact, there is little similarity between the alluvial and the non-alluvial tracts. The alluvial tracts have very flat longitudinal as well as cross country slopes as compared with conditions obtained in non-alluvial tracts. The small undulations of the country in alluvial tracts have no comparison with those in non-alluvial tracts. As a result of this, while a canal in alluvial tracts passes through a constant depth of utting for miles together in straight lengths, a canal in Deccan is serpentine in plan and its depth of cutting and height of canal bed above the ground level changes from chain to chain. Hard rock is met with in these tracts just a foot or two below ground level and the rate of excavation in rock is 6 to 10 times as much as that for excavation in softer materials at surface. Canals in non-alluvial tracts generally draw their supplies from reservoirs. As a result of this combined with the general nature of the country, the amount of silt carried in suspension by these

canals is very small and its nature is almost colloidal. These factors generally indicate the theories about bedfalls and width-to-depth ratios applicable to alluvial tracts can hardly apply to non-alluvial tracts. But there are a few canals in Deccan which have a portion (say 10% to 20%) of their length in full bank. It might be argued that the material of these banks as also the black soil and soft murum in cuttings can stand some comparison with the alluvium dealt with by Kennedy or Lacey. It is not therefore desirable to assume the inapplicability of these theories to our conditions without studying data and getting convincing reasons. It is the object of this paper to do so.

5. Data for Deccan canals is collected and presented in this paper with a view to finding out how far it agrees with Lacey's theory either generally or under particular conditions. Such investigation should necessarily precede any new lines for designs of canals on economical considerations.

6. In the following treatment, it is generally assumed that the reader is conversant with Mr. Kennedy's and Mr. Lacey's theory and formulae. Further as Mr. Lacey's theory is the latest of the silt theories, all comparison of data has been made on the lines and formulae of that theory. This can be done only by scanning the data available and finding out the value of the silt factor for each canal according to Mr. Lacey's theory.

The following abbreviations are used.

Q :—Discharge in cusecs.

V :—Velocity (in feet per second).

A :—Area of waterway.

W.P. or P :—Wetted perimeter.

R :—Hydraulic mean depth(H.M.D.)

Be :—Width at water surface of a semi-elliptic channel.

De :—Maximum depth of water in a semi-elliptic channel.

S :—Surface fall one unit in so many.

f :—Silt factor according to Lacey's theory.

Note :—As Lacey's theory gives a number of equations correlating his silt factor with other dimensions—silt factors are referred to as f_{Q-V}, f_{Q-S}, f_d etc., to indicate that values have been determined from data for velocity, discharge, surface-fall and diameter of silt particle. The suffixed alphabets indicate the data from which value of silt factor has been determined.

Abbreviations.

K.V.R. —Kinematic Viscosity Ratio.
F.S.L. —Full Supply Level.
W.D. —Water Depth.
N.L.B.C. —Nira Left Bank Canal.
N.R.B.C. —Nira Right Bank Canal.
M.R.B.C. —Mutha Right Bank Canal.
P.L.B.C. —Pravara Left Bank Canal.
P.R.B.C. —Pravara Right Bank Canal.
G.C. —Girna Canal.

Before studying the actual data, it must be made clear that our intention is not to determine what value of "f" is to be adopted if Lacey's theory is presupposed to hold good. Lacey has laid down certain equations which according to his theory hold good for channels under stable conditions. In order to test whether any channel has dimensions agreeing with Lacey, we must, *e.g.*, know the Q and "f" for that channel. In our channels, we know Q but not the "f". The only possible method under these circumstances is to find out values of "f" indicated by the discharge and some other dimensions like V, R, S, etc. If they agree with each other, within certain limits, applicability of Lacey principles can be said to exist. On the other hand, if value of "f" indicated by Q-V differs widely from value of "f" indicated by Q-De or from Q-S, then surely the Lacey principles cannot be said to apply. There should therefore be no misunderstanding on the point.

Some explanation is also probably needed as to what a regime channel is. A section which has had no trouble regarding scouring or silting for years together will for our purposes be taken as a stable channel. So long as it shows no

definite signs of changing from its existing section a channel is in regime. Most of the channels under inquiry are very old channels and some with age in excess of 50 years. The question of determining the correct "*f*" for a canal can arise only if we find that "*f*" shown by different dimensions such as Q,V,S,R, etc., for such channels agrees within reasonable limits. But if these values of "*f*" indicated by different dimensions for the same channel themselves show wide differences then any attempt on the lines of making a search for a section or sections in "knife edge final regime" and then determining the silt factor from the surface fall relationship in preference to the widely different values indicated by other relationships is not justified.

Scatter for any dimensions on log-paper is to be viewed with caution and in any case the general layout of every graph should agree with the trend of the equation for which we are testing before any agreement with Lacey's formulae can be said to be indicated. Simply drawing average values of "*f*" when trend is different is of no use.

Recently some explanations have been offered by Mr. Lacey in connection with small differences in "Sind Data" in values of "*f*" obtained by different equations. Lest it should be considered that these or similar explanations may apply to our conditions, some theoretical discussion is necessary. Not to encumber the main paper by these, the Author has dealt with these in Appendix No. 1. A study of this will help to show that any such explanations have to be looked to in our case with caution, and this is true of other cases as well.

7. With these preliminary remarks we may now proceed to discuss the data available for Deccan canals.

THE NIRA LEFT BANK CANAL.

It is proposed to scan data collected for the Nira Left Bank Canal first. This canal is situated in the Poona District of the Bombay Presidency, and was constructed more than 50 years ago. It was designed to discharge 450 cusecs originally. The actual discharge passing through the canal was however higher ever since the Great War due to an increasing demand for cane as a result of the high rate fetched by jaggery. This was possible due to the larger contents in the enlarged Lake Whiting at Bhatghar which had no demand on the recently constructed Nira Right Bank Canal. The Nira Left Bank Canal

was therefore remodelled in the year 1926-27 so as to carry a discharge of 720 cusecs. It should be noted that this remodelling in the first 64 miles of the canal consisted of nothing but the raising of side banks. The internal width or the shape of the canal were not touched to any extent worth the name, except in the case of three narrow rocky cuts. Some lengths in rock cuttings have recently been widened and some have been lined so as to accommodate the higher discharge required in the canal. The portion of canal between miles 64 and 100 were already remodelled by widening. This was easy as this portion of the canal was in the non-perennial section. The canal draws its water from a pick-up weir about 45′ high across the Nira River and except during monsoons draws its supplies from a reservoir at Bhatghar about 20 miles up-stream above the said weir. The canal has a length of 100 miles of which 64 were perennial till about 1923. This perennial length is now extended down to mile No. 75.

Hydraulic data was collected for this canal in the latter half of the year 1932. It will allow us to test whether it agreed with Lacey's theory and if so to determine the silt factor.

In collecting the data for this purpose, surveys were restricted to cross sections in full banks and in partial cuttings though some sections in full cuttings were also taken. Care was taken to select lengths in straight reaches though a few sections on curves were also surveyed. In any case all sections surveyed were in portions which were known to be stable. The survey for surface-fall offered the greatest difficulty. As already described cuttings and banks follow each other in quick succession on Deccan Canals and the surface-fall in full cuttings (not to mention the fall in narrow deep cuttings) is steeper than that in sections in full bank. In the case of canals in alluvial tracts, it is very easy to measure the surface-fall by averaging the same over a long distance. This is not possible under Deccan conditions. The surface-fall on N.L.B.C. is constant for not more than a few hundred feet and changes on either side. It was therefore essential to select a small length on either side of the cross section and then to find out the fall in this portion correct to the third place of decimal by very accurate survey in one setting of the levelling instrument. This detail is described here so as to leave no misunderstanding regarding the accuracy or otherwise of this data.

The next question is to determine what the regime discharge was. It is well known that silt berms form on the edges of a channel at a level which represents the F.S.L. for the regime discharge *i.e.*, a level at which the canal usually flows. It is obvious that this discharge is the average of the fluctuating full supply discharge. For the purpose of this survey, therefore, the canal was allowed to flow with its water just at or slightly below this silt berm. Discharges were actually measured at every 5 to 10 miles along the canal by Standing Wave Flumes or velocity rod measurements. Figures of intermediate discharges at the site of a section were derived from these by allowing for the actual draw off (measured by Standing Wave Flumes) in Distributaries on way and also for percolation losses. Statement A in Appendix II gives all the data for cross sections thus surveyed, the distance of every cross section being measured from the head of the canal, the area of waterway, the W.P., H.M.D., Velocity, water width at surface and maximum water depth, for the discharge being measured and interpolated as described above. In order to give an idea of the type of material at each of these sections, information has been given showing whether the said section was in bank or in partial cutting and if the latter whether the cutting was in soft material or in hard material like hard murum or rock.

We shall now proceed to scan the data.

In the first place, it will be noticed that the variation in practically each dimension for the same discharge is so large that it would be considered impossible to find one formula to cover all these points. Surface-fall, *e.g.*, varies from 1 in 3,000 to 1 in 30,000. Lest it should be thought that the flatter fall pertains to the higher discharges and the steeper to lower discharges, it may be explained that both extremes are met with in the higher as well as in the lower discharges. The same is true of velocities. They vary from 1·33 to 2·60 (even neglecting sections in hard cuttings). Here again it can by no means be said that higher discharges correspond to higher velocities. Generally speaking one may almost say that the velocity nearly everywhere along the canal is slightly less than 2 feet per second.

It will naturally be suggested that the large variation for the same discharge is due to sections in rock cuttings, murum cuttings, soil cuttings and those in bank being mixed

together. This by itself would, in the opinion of some, be sufficient to show that this is a canal where Lacey's or any formula on the lines of Lacey cannot hold good. We will however not stop at that.

In order to see whether there is any rule governing sections in made-banks and those in excavation in soft material, it was thought desirable to separate out sections in rock and murum. With this view the following graphs have been plotted on logarithmic paper for only soft cuttings and bank sections for various dimensions, against discharges.

1. Surface-fall.
2. Wetted perimeter.
3. Velocity.
4. Maximum water depth.
5. Width at surface of water.

A graph No. 6 is also plotted for areas against discharge. This is on ordinary graph paper. All these graphs are printed as accompaniments.

Obviously if Lacey's theory and formulae apply at least to these sections, we should expect to have points for these dimensions to lie on a continuous curve for some constant value of silt factor, with a limited amount of scatter.

It will be seen that the range of data for the main canal is from about 200 cusecs to about 600 cusecs. It will help matters if channels with smaller discharges were represented on the same graph. Data for distributaries and outlets taking off from the Nira Left Bank canal is therefore given in Statement B in Appendix II.

As in the case of sections on main canal, only points for soil and bank sections have been plotted for these small channels on the graphs, mentioned above. This allows a large range for discharges from 10 to 600 cusecs to be examined. Points with velocities below 0·8 ft. per second have not been plotted, lest they should vitiate data due to viscosity.

These graphs will now be discussed one by one :

We shall first examine the graph for surface-fall plotted against discharge. It will be seen that the points do not follow the line for any one silt factor. They lie between lines for silt factors equal to 0·3 and 1·4 for discharges of from 200 to 600 for the main canal. Most of the points lie between 0·5 to 0·8 the average being about 0·60.

In the case of lower discharges however, *i.e.*, 10 to 60 cusecs the points lie between lines for silt factors equal to 0·95 to 2·2. Most of the points for these lower discharges lie between 1·2 and 1·8 average being about 1·4.

Two facts are therefore noticeable. The variation is large even for the canal group or the distributary group by itself. Secondly the difference in "*f*" in canal group and the distributary group is beyond expectation. If both these channels carry the same type of silt it is not explainable for instance how the silt diameter (which according to Lacey is merely a function of the silt factor) can increase as it goes to the distributaries. Theoretically it may be possible to conceive that due to abrasion or deposition of heavier silt on way the silt particles may, if at all, get finer. Sind data for instance shows a change in this direction. In the case under consideration, however, the silt factor increases indicating that the diameter of the silt particle has increased.

However, before offering further remarks on the Q-S graph, it is better to examine the P-Q graph in view of the following quotations from note No. 4511 dated 27-11-36 by Mr. Lacey printed in the annual report of the Central Board of Irrigation for 1935-36.

"But the slope is not necessarily a function of Q, unless the wetted perimeter discharge relationship is faithfully reflected in the channel under consideration."

We will therefore now turn to the wetted perimeter discharge relationship. It will be seen on a reference to graph No. 2 for P-Q relationship for soil-bank data that this graph also shows wide scatter. (It need hardly be added that it differs from data for rock and murum very widely). If we neglect the very large amount of scatter and decide to get the equation indicated by the average layout of the Q-P points, the formulae

or the Nira Left Bank Canal may be written as $P = 2{\cdot}4Q^{0{\cdot}54}$ or if it is desired to keep the index of Q, the same as in Lacey's formulae, the data for the Nira L.B. Canal may be taken to indicate that $P = 2{\cdot}3\sqrt{Q}$ (about) against $2{\cdot}67\sqrt{Q}$ according to Lacey's theory. The wide range of variation on either side of the average line cannot be too strongly impressed; for instance, one gets the same wetted perimeter for two widely differing discharges as under :—

W.P.	Q varying	
	From	To
13·2	29·5	56 cusecs.
59	330	580 ,,

The same may be expressed better by noting that channels carrying the same discharge, *viz.*, 190 to 200 cusecs have wetted perimeter ranging between 26 and 40 and that all these sections appear to be stable.

It is therefore dubious whether or not the P-Q relationship would be taken as sufficiently agreeing with our data.

If the answer is in the negative, then we have to conclude that in the case of data for the Nira Left Bank Canal this important relationship does not hold good. The canal is running for a full half a century and even the increased regime discharge is now running for about 15 years. The canal is not having any trouble, such as silting or scouring in soil and bank sections for which data is plotted. This can well be judged by the fact that the annual requirements for silt removal on this canal are only about Rs. 20/- per year per mile. The canal cannot therefore be said to be not in regime.

However we may better assume that the P-Q relationship as represented by the above equations holds good sufficiently to allow the data to be put to the surface-fall test.

We may now go back once more to the scanning of the slope discharge data plotted on graph No. 1. The variation in the points for the main canal itself is very wide. The trend of the points for the canal group does not show any indications that "S" is a function of "f". We get channels for a discharge of about 200 cusecs to have any slope between 1 in 6,000 to 1 in 30,000. Similarly we get sections with about 600 cusecs having slopes as steep as one in 4,000 and as flat as one in 30,000. The same is true of the distributary group. Again there appears nothing in common between the two groups. If however an attempt is made to average out points in the two groups, the relationship indicated would be that $1/S \propto Q^{\frac{2}{3}}$ as against that indicated by Lacey's formula which lays down that $1/S \propto Q^{\frac{1}{6}}$.

Hence even if we presume that the P-Q relationship holds good it remains to be explained as to why the Q-S relationship falls out by such an extent. A possible explanation would be that the canal has not yet reached its final regime, though it has gone through the stage of the initial regime. Such an assumption would be a bold one in view of the age and the present satisfactory condition of the canal, as explained already. It may perhaps be said that even with the utmost care taken in observations some errors may have unavoidably crept in due to the difficulties encountered in finding out the surface-fall over such small lengths. Even allowing such an objection tentatively the explanation would be hardly convincing. There may be errors in individual points and scatter may have to be neglected but the trend of the average line should fit in with some constant silt factor over the whole range. This is however not borne out by graph No. 1. Nor is the scatter peculiar to this data only. We shall see similar scatter in other graphs.

Still another possible explanation for this disagreement may be the fact that the material of the soil and banks (and of course the hard murum and rock) is far from incoherent and is actually tenacious—a reasoning put forward by Mr. Lacey in explaining the discordant observations at serial No. 7 in the table in para 9 of note No. 4510 dated 27th October 1936, printed in the Annual Technical Report of the Central Board of Irrigation for 1935-1936.

Mr. Lacey explains as under regarding this discordant data at S. No. 7 for Sind, "That the high velocity reflected in the high value of f ($V \propto \sqrt{f} R$) was due to the great margin between

the velocity necessary to secure deposit of silt and the velocity necessary to secure scour." This is a clear explanation of Mr. Lacey's views, which have an important bearing on our problem. As will be seen later, our silt is so fine that it cannot deposit even with low velocities, while banks can stand any velocity upto 2′ per second or even higher and that is true also of the black soil. Other materials met with in Deccan can stand much higher velocities. It is highly doubtful therefore whether Mr. Lacey himself considers that his theory applies to such channels. Anyway we must proceed with our investigation as that theory does, according to some, apply at least partly if not wholly to Deccan. Besides there are others who believe that it applies to that tract under certain conditions.

We have so far discussed the P-Q and the Q-S relationship. We shall now proceed to consider the Q-V relationship. Please see graph No. 3. This graph showing discharge plotted against velocity is very interesting. One important point in regard to the observed velocities is that the chances of error in observations are extremely remote—almost nil—as they have been worked out by dividing accurate figures for discharges by actual areas of waterway.

Scanning the points as plotted, one cannot fail to notice the very large amount of scatter both in the canal group as well as in the distributary group. Whether averaging of so scattered a data is really permissible is a pertinent question. But even if we grant that, and draw a line so as to average all the available data restricted to soil cuttings and made banks what we get is a line nearly parallel to the X axis, indicating that the velocity did not vary with the discharge at all. According to Mr. Lacey's theory $Q \propto V^6$. If a line were drawn for the data for the Nira Left Bank Canal, it will be $Q \propto V^{\infty}$. In fact there is little difference in the velocities of (1) the distributary group for discharges between 10 and 60 cusecs only, and of (2) the canal group for discharges varying between 200 and 600 cusecs. This is a very dependable corroboration of the conclusions we were required to draw from the Q-S relationship. In fact the Q-V relationship test is very definite and one can see that any attempt to find out values of silt factor based on this relationship for the Nira Left Bank Canal is simply futile; because the data does not lie along the line for any one silt

factor or does not indicate that trend. But if it may help any readers to know the values of silt factors indicated by graph No. 3, it may be recorded that for the canal group the variation is between $f=0{\cdot}2$ to $f=1{\cdot}6$. About 0·7 may be said to be the average. Similarly for the distributary group the variation is between $f=0{\cdot}6$ and $f=5{\cdot}3$ the average being about 1·8. As in the Q-S group, the average silt factors for the canal group and the distributary group are exceptionally discordant.

It may at this stage be made clear that the variation in the temperature of water in Deccan is about 8° (20° to 28° centigrade) only and the K.V.R. for this variation is about 1·21 only. The possible error in velocity due to this Kinematic Viscosity Ratio can according to Mr. Lacey's explanation be about 2% $(1{\cdot}21^{\frac{1}{9}}-1)\ 100$ at the maximum. This variation is so minute that the graph paper cannot take that into account. The viscosity factor does not therefore help us out of the difficulty.

With a view to obtaining further corroboration, if corroboration were really needed, another graph has been plotted and this plotting has intentionally been done on ordinary paper instead of on a logarithmic paper. In this graph No. 6, discharges have been plotted against areas of waterway. As before variations are wide but what is more important is that no tendency to a "power curve" is indicated. A straight line curve is clearly the correct graph and the equation may be written as

$$\text{Area} = 0{\cdot}533\ Q$$

which really means nothing else than the fact we have already seen in the Q-V graph, *viz.*, that the velocity is 1·87 ft. per second on an average for all discharges and that it is independent of the discharge—a finding which cannot but be accepted as a clear proof of the fact that Mr. Lacey's theory and equations do not hold good for the Nira Left Bank Canal data even approximately. Still another graph would certainly be asked for, *viz.*, the V-R graph. This graph (not published) shows no better agreement than does the Q-V graph. The reason is obvious. Our data shows that the average V is constant while R definitely decreases with discharge from about 5·5 for 600 cusecs to about 1 for 10 cusecs. It is obvious therefore that the velocity is independent of the Hydraulic Mean Depth. To work out an average value of "f" from such data is certainly not justified.

Two more graphs have been plotted. In one of these, *viz.*, graph No. 4, the discharge is plotted against the water depth. Graphs for such a relationship have not (so far as the author is aware) been published for data for any of the canals in the Upper India alluvial tracts. The author however considers that if Mr. Lacey's theory be correct, this relationship should form an important guide and should be valuable in verifying, if not in determining, values of the silt factor where the data is indicative and concordant as regards the P-Q relationship. For one, the depth of water cannot be interfered with. It is measured very accurately by levelling instruments. Factors like silt removal are on record and cannot be lost sight of. So long therefore as sides of the canal are not held up by revetments, the water depth should provide very dependable data. The scanning of the graph for the Q-De relationship shows that data for canal group indicates values of "*f*" varying from about 0·2 to 0·9 the average being about 0·35. The silt factor for data for the distributary group varies from about 0·4 to 3·5, the average being about 0·6.

It will be noted that the silt factor indicated by this data is much smaller both for the main canal and for distributaries than that indicated by the Q-S or the Q-V curves. This is important.

We may also scan the Q-Be curve. Please see graph No. 5. A little explanation is perhaps necessary. The canal section is quite free to widen out at surface if the water would do so. No revetment is provided at these sections. If any interference is caused at all, it is in the direction of helping the sections to widen out at the water surface, by cutting off the silt berm when it grows so wide as to nearly overhang and fall down into the canal. Actually therefore the widths recorded may, if at all, be said to be slightly wider than what they would be if the sections were left to themselves and had no interference by human agency whatsoever existed. In any case if the channel had such a tendency, it could have widened in the period of 10 years prior to the survey and even afterwards.

The graph indicates that in the case of the canal group the silt factor varies from about nothing (or say 0·05) to infinity. The same is true of the distributary group also. If one may judge from the average line, the silt factor may be said to be

about 0·17 for the main canal and 0·25 for distributaries. These values are smaller than those indicated by the Q-De graph and much smaller than those indicated by the Q-V and Q-S graphs. How far this conclusion may be affected by the fact that the constant in the equation $P \quad CQ^{0.5}$ for the Nira L.B.C. data is 2·3 against 2·67 as per Mr. Lacey's formulae, is difficult to say.

Lest there should be any misunderstanding, it might be explained here, that when it is stated that Mr. Lacey's theory does not apply to Deccan, it is also meant to convey that the Kennedy theory is also not applicable. One sometimes comes across statements to the effect that certain channels in Deccan were in the past (*i.e.*, before Mr. Lacey's theory) designed on the Kennedy theory. This is definitely incorrect. The formulae on which design of canals in the Deccan have been based in the past are the stage discharge formulae like those of Kutter and Manning etc., and this was and is unavoidable as the major portion of Deccan Canals consists of murumy and rocky beds and also sides (partly).

There are two other points, the consideration of which can be said to have some bearing on the subject of our discussion. These are :—

1. The shape of the channel which according to Mr. Lacey's theory is semi-elliptic.

2. The silt load and size of silt in suspension and on bed of canal.

Regarding the former it may be explained that mere resemblance with a semi-ellipse is of but little value. According to Mr. Lacey a channel with a given silt factor and discharge will, even if designed incorrectly, attain regime in time and under these conditions the velocity, the width at surface and the maximum depth of water will have definite relations in accordance with certain formulae. In other words this means that the value of "*f*" *i.e.*, Mr. Lacey's silt factor indicated by Q-V, Q-De and Q-Be relationships will agree within reasonable limits. We have seen above that this does not occur. Mere resemblance in shape with a semi-ellipse does not therefore indicate that these channels follow Mr. Lacey's theory or his formulae.

Actually it is very doubtful if the shape of the channel of the Nira Left Bank Canal can be said to be semi-elliptic even in banks and soil cuttings.

What is however even more important is the fact that according to Mr. Lacey the ratio of width-to-depth in a channel is independent of the silt factor but depends upon velocity only. For values of velocity of the order of 2 ft. per second, the width-to-depth ratio in the channel should according to Mr. Lacey's formulae be of the order of 10′. However actual data for N.L.B. canal shows that this ratio varies between 5 and 7. Thus while Mr. Lacey's formulae require that for the actual ratio of width-to-depth in N.L.B. canal the velocity should have been 1·2 to 1·5 ft. per second, actually it is about 1·8 ft. per second.

The formation of silt berms is a matter which really deserve careful study. It is a botanical phenomenon and not purely Hydro-dynamic. But for the grass and its roots the shape of a channel at its edge would conform with the natural angle of repose of the wet soil. The fact that the silt berm is vertical is mainly responsible for giving to our irrigation channels an appearance resembling a semi-ellipse. As will be shown later, deposition of silt in a direct manner either on bed or on sides is impossible on Deccan canals except in some lengths below the head regulator of a canal or in a small portion below high velocity rock-cuts where bars of sand form locally and these can neither be called deposition of suspended silt nor "rolling" silt in the sense that the silt rolls slowly down to the tail of the canal.

So far as the Author's observations over a number of canals in Deccan show, the only possible source of silt deposition in corners and on the bed of our channels (except in cases mentioned above) is the silt berms which after full growth fall down in lumps and then slowly spread out on the sides and on the bed of channels (the silt berm forms again and repeats its life history). It is this rounding of the corners accompanied by the verticality of the grass-silt-berm, that gives the channel an appearance of a semi-ellipse. Superficial resemblance with a semi-ellipse does not therefore take us any nearer to Lacey's theory being accepted as applicable to our canals.

Regarding the silt-load and the size of silt in suspension in canal waters it may be explained that the silt load in the Nira Left Bank canal is so small that even if all silt conveyed by the canal in a year were deposited on the wetted perimeter this will hardly form a layer of ⅜th of an inch in thickness. Actually the silt is colloidal being about 0·008 millimeters in diameter and as such can never deposit on the canal bed or sides directly. Data regarding silt-load, size of silt particles in supension in canal water and also the diameter of material met with at bed and sides of the Nira Left Bank Canal has been collected. This shows that there is little resemblance between bed silt and side silt and that there is no comparison at all between the size of silt in suspension and that on bed or sides of the channel. As this is an important matter it has been discussed in full detail in Appendix No. III of this paper. Below are given a few important figures so as to allow comparison with conditions in alluvial tracts.

Item.	Nira Left Bank Canal (Deccan).	Jamrao Canal (Sind).
1. Silt load: parts by weight per 100,000 of canal water ..		
(a) Average for the year ..	15 to 20	100
(b) Maximum ..	50	400
(c) Size of silt particles in suspension (millimeters) ..	0·008	0·02 to 0·

These figures will speak for themselves about the paucity of the silt and impossibility of its deposition on the canal section. More details on this important problem will be found in Appendix III of this paper.

Summarising our findings based on the Nira Left Bank Canal data, we may in the first place record that the scatter for each and every one of the graphs is so wide that it will be incorrect to draw average lines as indicative of any mathematical rules for designs on the lines of Lacey's formulae. Even if average lines were drawn the trend of these lines is not at all in the direction of that indicated by Lacey's formulae for any definite value of "f". The velocity graph was independent of Q and the area graph indicated a straight line on an ordinary

graph paper thus corroborating the finding based on the Q-V graph. The same was the case with Q-S, Q-De and Q-Be relationships. But even if we tried to get at average silt factors indicated by each of these graphs, we have difficulty in the fact that the canal group and distributary group do not agree and the silt factor for each group has to be taken as different. The fact that instead of being lower than that for the canal group, the "f" for the distributary group is higher is astonishing. The following statement will give a comparative idea :

Graph.	Average silt-factor.		Remarks.
	Canal group.	Distributary group.	
Q-S	0·60	1·4	These values are found by averaging by the eye. No attempt on the lines of least squares is made as with the wide scatter such is not justified and the line indicated by the eye is correct enough for comparison.
Q-V	0·70	1·8	
Q-De	0·35	0·6	
Q-Be	0·17	0·25	

Further the width to depth ratio does not agree with that required by the average velocity. There is no hope of these differences being explained by viscosity, as K.V.R. is only 1·20, the variation in temperature being small (20° to 28° C.) usually.

To accept any one of these widely differing values shown in the table above and to adopt that for calculating the other dimensions of a channel under design would not obviously be justified. The only conclusion that could be drawn is that Lacey's theory and certainly the nature of his formula do not apply to the Nira Left Bank Canal even approximately.

We shall now turn to the data available from other canals. No other canal from the Deccan has been surveyed so fully with this view as the Nira Left Bank. However the first 25 miles of N.R.B.C. were surveyed during 1937 and this data will therefore be considered next.

THE NIRA RIGHT BANK CANAL.

This canal takes off from the same pick up weir at Vir from which the Nira Left Bank Canal does and draws its supplies from the same Lake whiting. Except for the fact that one of the canals is on the left bank and the other on the right

bank of the river, there is no difference as regards the physical, chemical, botanical, geographical or climatic conditions on the two canals. The Nira Right Bank was designed for a discharge of 1,500 cusecs with 8′ depth of water. It was opened in the year 1923. The regime discharge as indicated by the level of the silt berms is about 550 cusecs at head. In this respect also the two canals are comparable, the regime discharge of the N.L.B.C. being 588 cusecs at head. If we may speak of any difference in the two canals it may be said to be in their histories. The N.L.B.C. was originally (1887 A.D.) designed for 450 cusecs, but the discharge has slowly increased to about 600 and during periods of rush to 700 cusecs. This was achieved by simply allowing the depth of water to increase and by raising up the side banks in stages to allow the free board required above the increased F.S.L. On the other hand the Nira Right Bank Canal has been running for a discharge of about 1/5th and later on about 1/3rd of that for which it was designed. The result is that the N.L.B.C. is narrower and deeper while the N.R.B.C. is wider and shallower than what each was originally designed for. Actually both these canals run at present under identically similar conditions for some years past, both as regards the average discharge as well as the type quality and quantity of the silt. In other words we have reason to expect the silt factor to be the same in both these canals. Both canals have been running with a discharge of about 400 to 600 cusecs (and an average of somewhere about 550 cusecs) for several years. If Lacey's theory applies to the Deccan conditions one should certainly expect that in spite of the disparity in the shape of the two channels as constructed, they should make an appreciable effort to approach each other in their shape and other dimensions. Let us now examine how matters stand. Statement C in Appendix II shows dimensions of cross sections in miles 0 to 25 of the Nira Right Bank Canal.

As the range between the discharge at head and that in mile No. 25 is small *viz.*, 550 to 427 cusecs only, plotting this data will not be indicative. Comparing it with figures for the Nira Left will however be most instructive. Comparison of the two canals in the following lengths will be fair as they have the same range of discharge, *i.e.*, 540 down to about 440 cusecs.

N.L.B.C.—Miles 25 to 40.
N.R.B.C.—Miles 8 to 24.

The first 8 miles of the N.R.B.C. have been purposely left out, lest it should leave suspicion as regards heavy silting within the head reaches. The Author can however assure readers that the exclusion of these does not affect our findings in any way. Similarly the idea in taking averages of a number of points with a variation of 440 to 540 cusecs, is to allow local as well as observational errors to be nullified. Comparison of data for the same discharge on both canals will corroborate our findings even more strongly.

Let us compare the wetted perimeter first. The average on N.L.B.C. in soil and bank section is of the order of 56 feet, actual figures varying between 46 and 64. In the case of the N.R.B.C. the variation is from 79 to 90 the average being about 85. As the average discharge is the same, W.P. in both channels should, according to Lacey, be the same, *viz.*, 56 for the lower discharge of 440 cusecs and 61 for the higher, *viz.*, 540 cusecs, the average being about 59. The data for the Nira Right Bank Canal differs from this by nearly 50% even in its average. Even conceding that some variation in different sections is unavoidable, the average for the two canals is wide apart, 56 on N.L.B.C. and 83 on the N.R.B.C. Silt has, according to Lacey, no effect on the W.P.; but even the silt is of the same type on these two canals. To allow this to be visualized, the points for N.R.B.C. have been plotted on the graph for P-Q for N.L.B.C. and the group marked by a rectangle (see graph No. 2 for the N.L.B.C. data). The disparity is very apparent and shows that channels stand in regime for a wetted perimeter of anything between 46 and 87 for a discharge of 460 cusecs. This will, therefore, sufficiently demonstrate the dangers of assuming Lacey's formulae for P-Q as holding for Deccan.

The velocity on N.L.B.C. portion under comparison varies from 1·4 ft. to 2·4 ft., average being about 1·9 ft. per second. In the case of N.R.B.C. portion, the variation is from 1·13 to 1·57, the average being about 1·40. There is no agreement even here and the conclusion that can be drawn is that one may design the canal with any velocity as low as 1·10 or as high as 2·5 according to the slope one can afford to give and that there is no harm likely to be caused on that account.

The depth of water in the case of the N.R.B.C. is of the order of 5·25 feet on an average. That in the N.L.B.C. is of the order of 7·25 ft. for the same discharge. The same difference

is noticed regarding the surface width also. The average width for N.L.B.C. data within the range of discharge specified above is only about 52 ft. while that for N.R.B.C. data is 81 ft.

Again for a velocity of 1·4 ft. per second, the width to depth ratio should have been about 6·5. Actually however the width to depth ratio, in the length of N.R.B.C. under discussion where the velocity is 1·4 ft. per second, is 14 to 16. For such a ratio the velocity according to Lacey's formulae should be about 2·9 ft. per second.

A close examination of the present day sections discloses very interesting information. If we compare dimensions of the two channels with these as actually constructed originally, it is found that the original channel constructed for the N.R.B.C. is unchanged except for the rounding of at the corners at the bed and the small silt berm caused by grass at edges of water surface. Data for the N.L.B.C also shows the same. One finds that except for these slight but unavoidable changes the existing section agrees with the sections as originally constructed. In other words the basic principle that if the discharge and the silt factor is fixed, the size, shape, velocity, slope, surface, width, and the water depth is uniquely determined, is not at all borne out by these two canals which were designed on very different lines but carry the same type of silt and the same discharge for a long time. Had Lacey's theory been applicable, the N.R.B.C. should have narrowed down tremendously so as to agree at least approximately with the W.P., the surface width and W.D. indicated by Lacey's formulae. As it is, the W.P. and surface width are 50% in excess of that indicated by Lacey and there is no marked tendency for the same to reduce and approach Lacey's figure.

The same is true of the width to depth ratio. This ratio in the case of the portion under discussion of the N.L.B.C. is $\frac{52}{7{\cdot}25}=7{\cdot}2$ while the same for the N.R.B.C. is $\frac{81}{5{\cdot}52}=15{\cdot}4$.

We are not speaking of individual points but speaking of average of a number of sections having a known range of discharge under really comparable conditions and yet one channel has its $\frac{Be}{De}$ ratio twice as large as that of the other. It is therefore

not correct to say that channels under identical conditions need the same shape in their designs or that they try to take up that shape automatically.

Before closing the chapter on the data for the N.R.B.C. it may be mentioned that till 1933, this canal, like most other canals in the Deccan, was flowing continuously and consequently had weeds growing in it. Since that year rotational running (accompanied by closures at short intervals) has been introduced on the N.R.B.C. and weeds in it are now dying fast. It is noteworthy however that portions originally left unfilled 2′ below C.B.L. in full banks have not got filled up to any extent worth the name even by now. Lest this may be construed by some as indicative of an attempt on the part of the channel to have a bigger water depth, it may be explained that in other portions where material at bed is soft no change of the type of any scour below C.B.L. is noticed. In fact, the canal has some silting up in these lengths.

The table below shows values of "*f*" the silt factor indicated by data for the two canals within the range of discharges that allow a fair comparison.

Name of graph.	Nira Left Bank Canal.	Nira Right Bank Canal.	Remarks.
Q-S	0·6	0·7	Both Nira Left and Nira Right were designed for embankment sections with nearly the same slopes.
Q-V	0·55	0·25	
Q-De	0·35	0·70	
Q-Be	0·15	More than ∞	

Data for other canals is scanty but an attempt will be made to put such as is available. However it may be pointed out that most of the other Deccan canals except the Girna, have in the past suffered badly due to growth of aquatic weeds and data may not be considered by some to be on par with that for the two canals discussed above. However it is best to go through whatever is available and base our findings on what we

consider the data to be worth. If they corroborate our findings based on the data for the N.L.B.C. and the N.R.B.C. our conclusions will be strengthened.

THE MUTHA RIGHT BANK CANAL.

This canal was originally designed to carry a discharge of about 460 cusecs. Due to various reasons such as insufficient storage, large and continuous supply of potable water to Poona and heavy growth of aquatic weeds and consequent deposition of silt, it has never carried that discharge and at present it can carry a maximum discharge of about 350 cusecs. Regarding its regime discharge there is some difficulty in fixing it. A general average indicates 275 cusecs; while silt berm indicates about 340 cusecs. The silt berm is however not very marked.

Survey for regime sections has been made for 4 miles at head and dimensions found out for 16 sections.

As there is no change in discharge and in the canal section as designed for this length average of the dimensions for these 16 cross sections were worked out for a discharge of 340 cusecs. These gave the following values of "f" for different dimensions as under :—

Data
- Q = 340 cusecs.
- P = 59 ft.
- Area = 317 sq. feet.
- V = 1·10 feet./sec.
- Surface width = 54·4 ft.
- Depth = 9·62 ft.

This data gives the following results :

Results
- Constant "C" in Lacey's formula.
  $P = C\sqrt{Q}$ works out to 3·2
- f (Q-V) = 0·15
- f (De) = 0·15
- f (Be) = > ∞

The maximum width with $f = \infty$ should be only 50 ft. Actually it is more, *i.e.*, 54·4 ft.

It was therefore considered desirable to work out dimensions with a regime discharge of 275 cusecs to see if that showed any agreement. Figures for this discharge are given in statement "D" of Appendix II.

The canal is very badly infested with weeds and continues to be so because rotational running cannot be introduced, as water has to be continuously supplied to Poona to serve a population of 2½ lakhs. The canal takes off directly from the storage at Khadakwalsa, 10 miles from Poona. There is no separate pick up weir as in the case of many other Deccan canals. An important point about this data is that the canal is running for the last 50 years being of a longer standing than even the Nira Left Bank Canal.

As data is for a constant discharge, plotting on graph paper will not help and hence averages have been drawn and scatter neglected as in other cases.

Averages have been worked out for all the 16 sections and also for 12 sections leaving off the four rock cuts. It will be seen that the difference in the two averages is negligibly small.

The average wetted perimeter is 48 against 44 indicated by Lacey's formula. The constant in the formula $P = C\sqrt{Q}$ is therefore 2·87 against 2·67 of Lacey. This is just the reverse of what we found on the Nira Left Bank Canal but approaches the findings for the Nira Right Bank Canal.

The Q-V relationship indicates a value of $f = 0{\cdot}26$ while the Q-De relationship would indicate a value of 0·23. The agreement between these two is satisfactory, but the disagreement in the value indicated by the surface width is extremely unsatisfactory. The surface width indicated by these values of silt factors is 38′, while the actual average width is 44·2 feet. The discrepancy in the average, if any, could be wrong on the lower side, as some of the cross sections are in murum. The width in embankment sections alone is found to be larger still, *viz.*, 45 ft. Even if one works out the surface width with a value of silt factor equal to infinity the width should not according to Lacey be more than 44 ft. This discrepancy cannot be explained except by a reference to the fact that the canal was

constructed with a bed width of 23′ and side slopes of $1\frac{1}{2}$ to 1. A water depth of 7′ with these slopes requires a width of $2\frac{1}{2}$ plus 21 − 44 ft. slight variations being due to side slopes in hard materials being 1 to 1 or steeper or to the formation of small silt berms.

Similarly the water depth and velocity are what they would be expected to be with the channel as constructed, the actual discharge it carries, and the rugocity of the W.P.

The width to depth ratio agrees with that indicated by the average velocity, even in spite of wetted perimeter not agreeing.

The actual surface-fall is not observed. (The designed fall is 4″ per mile and if this exists a silt factor of 0·5 will be indicated).

THE GIRNA CANAL

No survey for this canal with a view to determining regime dimensions was made. However what little data the Author had collected in the year 1931 for some other purpose is worth scanning. This canal has its reservoir at Chankapur and pick-up weir at Thengoda in the Khandesh District, both these masonry works being across the River Girna, after which the canal is named. The canal was designed to carry a discharge of 90 cusecs at head with a bed width of 7·75 feet, a water depth of 3·5 feet and side slopes one to one, the bed fall being 3′ per mile. The section at tail end in mile No. 18 (13 miles of original project plus 5 miles of extension) was 6′ B.W., 2·5 W.D., and a bedfall of 4·5 ft. per mile, with a designed discharge of 47 cusecs. In softer materials and bank, side slopes were kept at $1\frac{1}{2}$ to 1.

In the year 1931, in which data was collected, the canal ran with a discharge of about 60 cusecs at berm level in head reaches and about 27 cusecs at tail. In the data collected all dimensions except the surface-fall are recorded. The canal was nearly free from aquatic weeds except at some places in the last few miles. It may be stated that the canal was probably the second best in the Deccan, as regards freedom from weeds, before the system of regular closures came into practice. The condition of the Girna Canal was thus satisfactory, there being no scour

except near aqueducts, where it is due to high velocities, caused by waterway being narrowed down, and cannot be attributed to the design of the channel.

Statement "E" in Appendix No. II gives Hydraulic data available for the Girna Canal.

The data has been plotted on a logarithmic graph paper. (See graph No. 7). As in the case of the Nira Left Bank Canal, points for murum and rock cuttings have been included in the statement but excluded in graphs. Four graphs have been drawn. The P-Q relationship shows that every point except one is below Lacey's line. In this respect it agrees with the Nira Left Bank Canal data, for discharges below 100 cusecs but the constant is only about 2·1. The Q-V-f data is also comparable with the Nira Left Bank Canal data. The result is worse, values of "f" varying from 1 to 5, the average being about 2, as against 1·7 for the Nira Left Bank Canal. What is most important is that velocity does not show any relationship with the discharge.

The scatter both in P-Q as well as V-Q and other graphs is excessive. The Q-De curve shows values of "f" varying from about 0·5 to 3 as in the Nira Left Bank Canal data. The average "f" indicated by this data however is about 1 for Girna Canal as against about 0·6 for distributaries of the Nira Left Bank Canal.

The Q-Be points also show similarity to the Nira Left Bank Canal data for distributaries, the majority of points indicating a value of $f=0·2$, which compares favourably (if such a comparison may be made) with the value indicated by the diameter of the almost collodial silt particle in suspension carried by waters in Deccan Canals.

It will however be interesting to note that widths at water surface are what they have been constructed to be. Thus, for lengths in cutting in harder stuff in head reaches, the width is expected to be 12′ to 15′ to suit the bed width of 7·25′ and side slopes 1 to 1 with W.D. varying from 2 ft. to 3 ft. The same is expected to be 16′ to 18′ for lengths in banks constructed with side slopes of 1½ to 1. These agree with actual figures. This is seen in other reaches of the canal as well. Except for small silt berms or scour below high velocity aqueducts, there has been no change worth the mention.

The Girna Canal data is therefore a very important corroboration of nearly each one of our findings based on the Nira Left Bank Canal data. The N.L.B.C. data had left some doubt as to whether the higher values of silt factor indicated by the distributary data (as compared with the canal data) was due to the fact that distributary channels draw larger proportions of silt or draw heavier silt from the canal bed. We see from the Girna Canal that the main canal itself drawing from the pick-up weir direct shows fair comparison with distributaries taking off from the Nira Left Bank Canal and not with the main N.L.B. Canal. It is therefore clear that even when we draw the same type of silt from the pick-up weir, the value of "f" in the Nira Left Bank Canal is definitely below 0·8 while that in Girna approaches 2. In other words, instead of being constant, "f" increases with a fall in the discharge if we base values of "f" on the Q-V relationship—a fact which is exactly the opposite of what one may expect from Lacey's theory.

This anomaly has obviously arisen as a result of our applying the alluvial silt theory to non-alluvial channels, and is sufficient to show the inapplicability of Lacey or the Kennedy theory to our canals.

THE PRAVARA LEFT BANK CANAL.

The data about regime sections on this canal may also be said to be scanty as no survey on proper lines was made. However, cross sections had been surveyed in the year 1935 for some other purpose. As these cross sections show the silt berm very clearly, we know the regime F.S.L. and hence also some other regime dimensions, *viz.*, the area, the wetted perimeter and the Hydraulic mean depth. The average surface-fall is known but actual local fall at each section has not been measured. It has however to be noted that the P.L.B. Canal was not designed with different falls for banks and for partial and full cuttings as in the case of the Nira Left Bank Canal. In fact down to mile No. 16, there is no high velocity deep cut on the P.L.B.C.

The regime discharge is however not very reliably known though approximate figures are available, being based on velocity observations on gauge runs. The accuracy of these is not comparable with that obtained on Standing Wave Flumes. Again the Pravara Canal was infested with aquatic weeds as in

the case of the Mutha Right Bank Canal. The discharge passing through the canal immediately after a clearance of weeds was about 435 cusecs, though the canal was designed for a discharge of 530 cusecs. As the growth of weeds advanced—and this happened very rapidly in the cold season—the discharge dropped down to about 200 cusecs or even less for the same F.S.L.

The difficulty therefore lies in saying what should be considered as the regime discharge under these circumstances. The Author is inclined to think that the regime discharge should still be taken as 425 cusecs. as the fall in discharge was due to the lower half of the waterway being blocked by weeds and conditions in the upper area were comparable with these obtained when the full discharge of 425 cusecs flowed.

However, it is likely that opinions may perhaps differ. There is therefore some difficulty in discussing the limited amount of data that is available. It was not therefore thought advisable to find out all the dimensions at each of the cross sections surveyed and hence the Author has worked out approximate but representative figures from the average typical sections one for each mile. (This data may be taken for what it may be worth but it is certainly not far from the actual average conditions).

Attention may be drawn to small difference in the two types of averages worked out for the Mutha Canal data (see Statement "D" in Appendix II). Both the P.L.B.C. and M.R.B.C. were designed with little change (except side slopes) in embankment and in balancing sections. The procedure followed is therefore not far from correct.

Statement "F" in Appendix II gives Hydraulic data for the Pravara Left Bank Canal.

We shall now try to scan this data, approximate as it is, sections having been selected as typical to represent general average conditions. As data available is only for a small range of discharges, plotting the same will not be useful. However, considering the fact that the variation in discharge in the first 9 miles is small, we may compare the data with Lacey's formulae assuming 420 as the average discharge.

The wetted perimeter required for this by Lacey's formula is 54′ while actual average is only about 45′. There is however nothing astonishing in this. Our Nira Left Bank Canal data

has shown that the W.P. there follows the rule $P = 2.3\sqrt{Q}$ and our average for Pravara Left Bank agrees with this very fairly. The Girna Canal data also compares well. The other dimensions of channels for the portion of the Nira Left Bank Canal where regime discharge is of the order of 420 cusecs, also agree very closely as will be seen from the following :—

Average dimensions for about 420 cusecs.	Pravara Left Bank Canal	Nira Left Bank Canal	Nira Right Bank Canal
Velocity	2.03	2.00	1.3
Area	208	210	320
Surface width (between berms)	40	42	78
Central depth	6.6	6.4	5
Wetted perimeter	45	48	81

However a comparison with both the Nira Canals which are known to be stable will show that the sections of the Pravara agree in all dimensions with those on the Nira Left Bank Canal, but differ widely from those for the Nira Right Bank Canal. If however one tries to study with a view to finding out reasons why these 3 channels possess the sections they actually have, one has to get down to the dimensions with which these channels were constructed. The Nira Right Bank Canal was designed in the length which at present carries 420 cusecs with a bed width of 60 feet and side slopes of two to one in embankment sections. The canal is carrying a discharge smaller than for which it was originally designed and this requires a depth of water equal to only about 5′. The width at water surface for this depth with the sections as constructed was 80 ft. As small berms formed as usual, actual width is about 78′. There is no connection with Lacey's or Kennedy's theory in this.

In partial cuttings the sides are excavated with $1\frac{1}{2}$ to 1 or with 1 to 1 slopes but 2′ berms are left at the ground level in actual construction, with the result that width at water surface is nearly the same, there being slight local variations from place to place.

The reason why depth of water for 420 cusecs is 5′ can also be directly verified by the usual type of calculations with the Kutter's formula.

Similarly the Nira Left Bank Canal was constructed at points where the discharge is 420 cusecs at present, with a bed width of 20′ and side slopes $1\frac{1}{2}$ to 1. The water depth required for this discharge is about 6′ to 6·5′. The width at surface is therefore 38′ to 40′ or slightly more where berms were left at ground level. The same is seen in the case of the Pravara Left Bank Canal also.

Hence it will be noted that the dimensions of the channel as they stand have nothing to do with silt theories like those of Kennedy or Lacey but they are what they had been constructed except for such small changes as a little grass berm at edges. For similar reasons the wetted perimeter is what the channel was given when constructed. None of the 3 channels has caused trouble because of shape as constructed being different from that required as per Lacey's theory. The same will be seen in the case of the other channels for which data has been put forward.

Values of silt factors indicated by different dimensions for the P.L.B.C. do not, also, agree. They are :—

$$f_V = 0{\cdot}80$$
$$f_{De} = 0{\cdot}40$$
$$f_{Be} = 0{\cdot}1$$
$$C \text{ (in } P = C\sqrt{Q}) = 2{\cdot}3$$

It may be claimed by some that it is incorrect to call the Pravara Left Bank Canal prior to remodelling in 1936 as a stable channel and hence that its comparison with the Nira Left Bank Canal or any other canal is not justified. To make matters clear we give below a history of the Pravara Left Bank Canal.

The Pravara Left Bank Canal has its reservoir at Bhandardara formed by a dam across the Pravara River. The canal starts from a pick-up weir, several miles further down the same river, at Ozar about 5 miles away from Sangamner, in the Ahmednagar District. Two canals take off from this weir one on each bank of the river. The Left Bank Canal now under discussion was designed to discharge 530 cusecs with 8′ depth of water at head. The depth of water was slowly reduced to 6·3 in mile

No. 9, the designed slope at surface being 0·63 ft. per mile while that for bed was 0·44 ft. per mile. The designed discharge was the same throughout this length and to make this possible the bed width which was only 25·5 ft. at head was slowly increased to 36 ft. in mile No. 9 to correspond there to a water depth of 6·3′. From there onwards the bedfall was kept at 0·75 ft. per mile and this was practically the same as the surface-fall down to mile 16.

Soon after opening the canal (about 1920), the head reaches began to get heavy deposits of sand and shingle with some silt in it and the removal of this began to cause difficulties in management and to consume large amounts of money annually. Even after removal, the sand bar formed again very shortly afterwards. As may be expected, the F.S.L. above this sand bar rose.

Really speaking such a bar of shingle or sand below head regulator forms across every canal in the Deccan, particularly where the height of pick-up weir is small. A similar sand bar has formed across the Pravara Right Bank Canal also. But little difficulty was felt, as all that was necessary to set matters right on the canal was to raise the side banks where necessary so as to allow for the afflux. This was possible on the Pravara Right but not on the Pravara Left. The Right Bank Canal had a designed depth of water of 5 ft. only while the Left Bank had a designed depth of 8′. The bar of about 2 ft. on the Pravara Left Bank and 2·5 ft. on Pravara Right Bank raised this by a similar height and thus the depth of water required to carry the designed discharge, in the length affected by the sand bar, was 8 ft. or so in the case of P.R.B.C. and that necessary on the Pravara Left was about 10 ft. or more. The height of pick-up weir above C.B.L. of either canal was however only 9 ft. and a small head was surely needed for forcing the discharge through the head regulator. The result was that the Pravara Left could never run to a depth of more than about 8·5 ft. at head, and even this depth would require the basin to be filled to the brim. As it is not possible to get so fine a working in actual practice, the discharge was limited to that which the canal could carry with a depth of a little over 8 ft. and this amounted to only about 425 cusecs.

In the case of the Right Bank Canal, however, there was no difficulty. With even 8·5 ft. depth of water in the Osar weir,

that Canal could easily draw any depth upto 8 ft. in it and no difficulty was therefore experienced on that Canal in spite of the sand bar and silting up in the head reaches.

The formation of the sand bar in the head reaches of the Pravara Left Bank Canal led some to believe that there was something wrong in the design of the channel itself. Some attributed the formation of this sand bar to the fact that the bed was not parallel to the designed surface of water, depth in mile 1 being 8 ft. and that in mile 9 being 6·3 ft. (and bedfall being 0·44 and the surface-fall 0·63 ft. per mile). It was suspected that as a result of this the bed was trying to get parallel to the surface of water. There were also others who considered that the whole trouble was an outcome of insufficient fall available to the canal in the head reaches and the consequent low velocity. The latest idea was based on Lacey's theory and an assumption that the channel was wrong in its shape and that if it had a proper shape there would be no trouble.

The supposition that the P. L. B. C. was incorrectly designed and was, as a result, silting in head reaches due to (1) surface-fall being different from bedfall, or (2) smaller surface-fall than what was necessary, or (3) wrong shape of channel, has no evidence to support it. This can very well be seen from the fact that a sand bar on the lines of the Pravara Left is formed in the head reaches of other Deccan canals also. As pointed out already it exists on the Pravara Right Bank Canal. It exists on the Nira Left Bank Canal, the Godavari Canals, and also the Mutha Right Bank Canal, in short on every Deccan canal.

In fact the depth of the sand bar on the Nira Left Bank and Paravara Right Bank Canals is larger than on the Pravara Left Bank Canal. The Pravara Right Bank Canal had been designed with a bedfall equal to the surface-fall, *i.e.*, with a constant depth of water in the head reaches. Similarly the Nira Left Bank had been designed with the same bedfall as the surface-fall and had a good velocity. All the same a sand bar has been formed in the head reaches of that canal also and this is in every way comparable with the sand bar formed in the head reaches of the Pravara Left Bank Canal. If Lacey's theory were applicable to our canals, the Pravara Right Bank Canal also should have needed change in shape in

head reaches where the canal has silted heavily. Actually we find that it is running in its designed shape without any trouble ever since the weeds have died.

It is needless to add that other portions of Pravara Right and Left Bank Canals are working quite satisfactorily, though the shape is quite different from that required by Lacey's theory and formulae. And we have seen that N.L.B.C. and N.R.B.C. have stable channels in spite of width to depth ratio not agreeing with that required for the velocity of water in the two canals respectively.

It will, therefore be seen that the section of the P.L.B.C. before remodelling was in regime to the extent to which Nira L.B.C., N.R.B.C. and P.R.B.C. were. The trouble was the limited height of the pick-up weir and weeds—a problem not connected with silt theories of Kennedy or Lacey. Data for the P.L.B.C. sections before remodelling is therefore as reliable as the data from other canals and adds to the rest to prove the inapplicability of Lacey's theory to the Deccan conditions in general or under any particular situations.

It is necessary to add that the necessity for remodelling the Pravara Left Bank Canal for meeting the increasing demands on the canal was quite another matter. What is important is that this remodelling was not needed because the shape was wrong or because the surface-fall and bedfall were different.

RIVERS IN DECCAN.

The paper would perhaps not be complete without data for rivers. Data for stable sections of rivers in Deccan is available to some extent. It is not however proposed to produce it here and to discuss the same, as our intention is to discuss canals. It may, however, be recorded that so far as data available shows, no agreement with Lacey is indicated and wetted perimeters are found to differ by 40% to 150% in the case of stable sections chosen as gauging sites. It may also be added that values of silt factor indicated by different dimensions for the same section do not agree.

SUMMARY.

The following statement gives a summary of values of silt factor for all the channels for which we have discussed data. Lest there may be any misunderstanding, the Author would

again like to repeat that the intention in finding out values of "*f*" indicated by each of the four relationships for each canal, is to find out if there is any similarity in the values indicated by any one canal, or in any particular relationship by all canals or both. It is not intended to say, *e. g.*, that a value of "*f*" given by the Q-Be relationship should be adopted. But if "*f*" indicated by the Q-Be and the Q-De graphs differ widely then surely the shape does not agree with Lacey. Similarly if f_{QV} is far different from either or both of these then also the same conclusion has to be drawn. The comparison of the silt factors worked out from different dimensions is the only possible test for agreement or otherwise with Lacey's formulae.

All these canals are old, some of them more than 50 years. Except as a result of weed growth, there has been no trouble in maintenance, and rotational running of canals has successfully put an end to that difficulty. If it is claimed by some that "Regime conditions" are not obtained on these canals even with this age, it is obvious that the rate of change is extremely slow and obviously there is no reason to worry over the canal being in regime or not. As a matter of fact, such an assumption is not borne out by any data on record.

The following table may now be studied :—

Statement showing values of "*f*" by different dimensions for various canals in Deccan.

Name of Canal	Mileage tested		Values of *f* indicated by various relationships					Age of Canal Years	Remarks
	From	To	Q S	Q-V	Q-De	Q-Be	Value for C in $P=C\sqrt{Q}$		
Nira Left Bank Canal	0	100	0·6	0·70	0·35	0·17	2·4	50	The values of "*f*" are average values, scatter being neglected
Distributaries on Nira Left Bank Canal in the same length			1·4	1·80	0·60	0·25	2·1	—50	
Nira Right Bank Canal	0	25	0·7	0·25	0·70	Infinity	3·84	15	
Mutha Right Bank Canal	0	4	Not available.	0·26	0·23	,,	2·87	50	
Girna Canal	0	18	Not available.	2·00	1·00	0·20	2·1	25	
Pravara Left B Canal	0	9		0·80	0·40	0·1	2·3	20	

GENERAL FINDINGS BASED ON DATA DISCUSSED IN THE PAPER

With the data discussed above for canals and distributaries in the Bombay Deccan, one is led to draw the following conclusions .—

1. There is not even one canal in Deccan which follows Lacey's theory in all its dimensions, *i.e.*, has the same value of "f" in the various relationships or where trend of graphs agrees with that indicated by Lacey's equation for a given silt factor.

2. This is particularly noticeable about the Be and De dimensions, *i.e.*, about shape, the width to depth ratio and also about the Q-V relationship.

3. The surface width and wetted perimeter as it now exists is practically what it was constructed originally and but for the small silt berm there is no change worth the mention.

4. The water depth is regulated by Kutter's formulae, but changes locally due to heading up above narrow cuts or aqueducts and also local sand bars formed below head regulators, etc. The formation of this sand bar has no connection with Lacey's shape or theory.

5. The silt carried in suspension is very small in quantity (15 to 20 parts per 100,000) and what is more important is that it is almost colloidal, the size seen under microscope being 0·007 millimeter in diameter corresponding to a silt factor of 0·13. Samples of bed silt are confusing and do not help to determine f_d.

Even if all silt conveyed by canals were to deposit, it would take 15 to 20 years before any effect can be noticed. Actually due to its almost microscopic size, not even a small fraction can deposit except as a result of aquatic weeds or the toppling over of overgrown berms.

6. The silting up of corners of the channels is through the medium of the silt berms which is a biological and not a purely Hydrodynamic phenomenon and will continue to occur whatever the shape of the channel. The average diameter of the silt on bed and sides does not agree with that of the silt in suspension even if sand were neglected.

7. Velocities do not vary with discharge and a channel with 10 cusecs is seen to stand the same velocity as one carrying 600 cusecs on the same canal system. To draw conclusions about average silt factor indicated by Q-V or V-R relationships is therefore incorrect in the case of canals in Deccan.

8. Data about surface fall (actual) is scanty being available on only two canals and perhaps may not be considered very dependable as chances of observational errors exist. This is due to surface-fall changing from place to place.

But our finding No. 7 clearly shows that the latitude allowable in fixing the surface-fall for any particular canal is very great, so that we may design a channel with a surface-fall to suit our requirements and need not be bound down by the silt theories like those of Mr. Lacey.

9. Existence of weeds in canals has no relation to Lacey's theory, and channels having weeds as well as those free from that pest equally disagree with Mr. Lacey's formulae and dimensions indicated by the same.

10. There is disagreement between average values of silt factor for distributary and the main canal both of the same system as worked out by the same, *viz.*, the Q-V (or the V-R) relationship, 0·70 being the factor indicated by the canal data and 1·70 by the distributary data on the Nira Left Bank Canal.

Further the fact that data for the main Girna Canal shows a value of "*f*" = 2 which agrees with distributary data for the N.L.B.C. and not with the canal data, shows definitely that silt factor for channels with smaller discharges is higher. This is contrary to Lacey's theory.

11. The fact that silt factor indicated for the Nira Right Bank Canal by the Q-V relationship is only 0·25, while that for the N.L.B.C. is 0·70 is extremely important, as both the Nira Left Bank Canal and the Nira Right Bank Canal draw from the same pick-up weir.

The disparity in values of "*f*" indicated by the N.L.B.C. and the N.R.B.C. is very conclusive in showing that it is incorrect to accept or insist upon any silt factor for the design of any new canal or remodelling an existing canal in the Deccan. This is strongly corroborated by data for other canals.

12. The resemblance to semi-elliptic shape is only superficial and probably imaginary and this is borne out by the important fact that canals with low values of silt factor of the order of 0·25 indicated by the Q-V relationship are wide and shallow while canals with high values of silt factor are comparatively narrow and deep, whereas the very opposite should be the case, if Lacey's theory applied. The resemblance is therefore not based on mathematical considerations, which would require that Q-Be and Q-De relationships should give values of "f" agreeing with each other and with "f" indicated by Q-V.

13. The width-to-depth ratios do not agree with those required for velocities according to Lacey's formulae.

ECONOMICS OF DECCAN CANALS AND LACEY'S THEORY.

We have thus far studied how far data from existing Deccan canals agrees with Lacey's theory and seen that it does not do so at all. But we should not leave the question there. It remains to be seen as to why we may not design according to that theory, if that does not cause any harm, even if there is no gain.

This will require very careful consideration. This will be done in other parts of this series on "The Economics of Designs of Deccan Canals."

The paper is accompanied by 3 appendices.

APPENDIX No. I

A note regarding difference in values of "f" for the same channel as obtained by Lacey's different formulae

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The exact meaning of Lacey's silt factor is not very clear. Originally it was thought to be a function of the diameter of the silt particle and it was expected that the values of silt factor from Lacey's different equations would tally with each other for any stable channel.

Afterwards it was found that the values of silt factor from different equations differ very much ; and hence the terminology f_{QV} f_{VR} f_d etc., came into existence. It was also revealed that physical dimensions of "f", as obtained from Lacey's different equations are not the same, thus

(1) $V \propto \sqrt{fR}$, Dimensions of f_{V-R} are

$$\frac{V^2}{R} = \frac{L^2}{T^2\,L} = \frac{L}{T^2} \quad (\textit{i.e.}\ \text{acceleration}).$$

(2) $f \propto \sqrt{d}$; Dimensions of f_d. are $d^{\frac{1}{2}} = L^{\frac{1}{2}}$

(3) $S \propto \dfrac{f^{\frac{5}{3}}}{Q^{\frac{1}{6}}}$; Dimensions of $f_{Q\text{-}S}$ are $\dfrac{L^{\frac{3}{10}}}{T^{\frac{1}{10}}}$

(4) $S = 380{\cdot}6 \times 10^{-6} \times f^{1\cdot 5} \times R^{-\frac{1}{2}}$ (Called as Improved Regime slope formula. Mr. Lacey's note No. 4511 of Central Board of Irrigation dated 27th Oct. 1936).

Dimensions of $f_{R\text{-}S}$ are $L^{\frac{1}{3}}$.

With these different dimensions of "f", as obtained from Lacey's equations, it is no wonder that the nature of Lacey's silt factor is uncertain.

The Author of this paper, would like to point out that dimensions of "f" for the above formulae differ because the dimensions of "f" in the very basic equations do not tally, for

$$\text{(I)}\quad V \propto \sqrt{fR}\,; \quad \text{Dimensions of } f \text{ are } \frac{L}{T^2}$$

$$\text{(II)}\quad Af^2 \propto V^5\,; \quad \text{Dimensions of } f \text{ are}$$

$$\frac{L^{1\cdot5}}{T^{2\cdot5}} = \frac{L}{T^2}\left(\frac{L}{T}\right)^{0\cdot5}$$

Thus the two basic Lacey's formulae do not agree mathematically; and hence also all other formulae 1, 2, 3, 4 above, which have been derived from these.

Efforts are sometimes made to account for the difference in dimensions of "f" by bringing in the effects of gravity, kinematic viscosity, etc., and by manipulating their powers, so as to make good the missing dimensions, whatever they are in each case—powers of gravity, viscosity, etc. not being based on considerations of theoretical reasoning. In his note No. 4516 of the Central Board of Irrigation of 27th October 1936, Mr. Lacey explains the dimensions of "f" in (4) above as

$$\frac{g^{\frac{10}{9}} \cdot R^{\frac{1}{6}} \cdot S^{\frac{2}{3}}}{\nu^{\frac{2}{9}}}$$

Certain scientists in Punjab have advanced anti-arguments, based on theoretical reasoning and also on actual data, to show that the effect of viscosity in open channels is negligible. It has already been shown in the body of the main paper that effects of viscosity in Deccan Canals are altogether too negligible to explain the differences in values of "f" obtained from Lacey's different formulae.

Applying the test of dimensions to Lacey's P-Q relationship $P \propto Q^{0\cdot5}$, it can be seen that the dimensions do not tally ($L = L.V^{0\cdot5}$). In this formula, the silt factor "f" does not exist at all and still the dimensions of the two sides of the equation are different.

Thus it will be seen that if Lacey's formulae are to be accepted, a fresh and an arbitrary manipulation of unknown factors is required to explain each of his formulae.

APPENDIX II
Statements A to F.

APPENDIX No. III

DATA AND DISCUSSION ABOUT SILT LOAD, SIZE OF SILT IN SUSPENSION AND ON BED AND SIDES OF THE NIRA LEFT BANK CANAL.

In the case of alluvial canals as those in Sind, *e.g.*, the silt in bed sides and berms agrees with each other, at least to some extent as regards the size of the average silt particle. The average silt particle held in suspension in the canal waters is also comparable with these though the latter is just about one half as large only. Conditions in Deccan canals are however very different. Even neglecting the pieces of sand and kankar met with in samples from the bed and sides, the remaining silt too is far different in size and structure from the silt carried in suspension by waters in the canals.

Data about silt on bed and sides of the Nira Left Bank Canal is printed and discussed later on. Before studying the data we shall consider data about the quantity of silt carried in suspension by the waters in the Nira Left Bank Canal. The amount of silt transported per 100,000 parts of water and the diameter of the silt particle are very important factors connected with the subject under discussion. A statement showing the analysis of silt in samples of canal waters at various points along the Nira Left Bank Canal for the period from August 1933 to March 1934, analysed by Mr. R. P. Talati, B. Ag., at the laboratory at Malegaon Colony on the Nira Left Bank Canal is printed overleaf.

Analysis of suspended Silt in waters on the Nira Left Bank Canal.

[illegible]	I. Nira Mile No. 9 Furlong No. 1. Silt % Total	2 H	4 H	Canal gauge.	Remarks.	II. Vadgaon Mile No. 24 Furlong No. 2. Silt % Total	2 H	4 H	Canal gauge.	Remarks.
[illegible]-33	·028	·016	·0*	7·70	* Result peculiar and differs from the rest.	·040	·020	·020	9·05	Average diameter - 0·0086
[illegible]-33	·016	·012	·006	8·10		·020	·020	·016	8·30	
[illegible]-33	·018	·018	·010	7·20		·026	·024	·006	8·00	
[illegible]-9-33	·024	·020	·020	7·10		·038	·020	·018	7·0	
[illegible]-10-33	·028	·018	·016	7·10		·036	·034	·024	8·0	
22-10-33	·028	·014	·010	3·8		·022	·014	·014	3·8	
30-10-33	·030	·020	·016	6·5		·030	·024	·020	7·2	
2-11-33	·020	·014	·012	8·1	Average diameter—0·0101	·020	·014	·008	8·2	
16-11-33	·018	·010	·010	8·1		·024	·014	·014	8·8	
27-11-33	·014	·008	·006	8·8		·018	·010	·010	8·4	
5-12-33	·030	·014	·010	8·4		·020	·014	·014	8·8	
15-12-33	·014	·010	·008	8·4		·030	·020	·014	8·8	
26-12-33	·030	·020	·010	8·3		·020	·014	·012	8·6	
6-1-34	·020	·014	·014	8·4		·022	012	010	8·4	
17-1-34	·050	·030	·024	8·4		·050	·026	·020	8·30	
26-1-34	·050	·020	·014	8·2		·020	·016	·010	8·70	
7-2-34	·034	·020	·010	8·4		·024	·018	014	8·40	
17-2-34	·050	·020	·014	8·5		·050	·024	·020	8·70	
27-2-34	·044	·024	·016	8·4		·046	·034	·020	8·50	
7-3-34	·040	·020	·012	8·3		030	·024	·018	8·10	
Total	·576	·342	·238			0·586	0·396	0·302		
Average Silt contents.	·029					0·029				

[illegible]	III. Pandhara Mile No. 37 Furlong No. 3. Silt % Total	2 H	4 H	Canal gauge.	Remarks.	IV. Baramati Mile No. 47 Furlong No. 7. Silt % Total	2 H	4 H	Canal gauge.	Remarks.
[illegible]-33	0·052	0·052	0·016	9·30	Average diameter - 0·0078	0·032	0·020	0·020	8·30	Average diameter = ·0057
[illegible]-33	0·014	0·014	0·012	8·00		0·030	0·012	0·010	5·70	
[illegible]-33	0·024	0·020	0·012	7·60		0·024	0·024	0·008	6·20	
[illegible]-9-33	0·028	0·020	0·020	6·8		0·030	0·030	0·024	4·4	
[illegible]-10-33	0·024	0·022	0·014	8·2		0·038	0·034	0·024	7·3	
22-10-33	0·024	0·014	0·010	5·5		0·020	0·018	0·016	4·2	
30-10-33	0·024	0·020	0·014	7·6		0·020	0·020	0·008	6·6	
2-11-33	0·028	0·018	0·014	7·5		0·024	0·028	0·016	4·9	
16-11-33	0·020	0·018	0·010	8·8		0·014	0·020	0·010	8·1	
27-11-33	0·020	0·016	0·010	8·0		0·020	0·014	0·010		
5-12-33	0·034	0·020	0·020	8·1		0·024	0·016	0·014	5·7	
15-12-33	0·026	0·018	0·016	8·05		0·024	0·014	0·014	6·0	
26-12-33	0·020	0·016	0·010	8·35		0·026	0·014	0·012	6·4	
6-1-34	0·020	0·014	0·010	8·15		0·024	0·020	0·014	5·8	
17-1-34	0·054	0·040	0·030	8·00		0·046	0·030	0·020	6·30	
26-1-34	0·030	0·020	0·010	7·80		0·032	0·026	0·016	6·0	
7-2-34	0·030	0·020	0·012	8·05		0·030	0·018	0·010	6·2	
17-2-34	0·040	0·022	0·010	8·3		0·044	0·020	0·016	7·90	
27-2-34	0·048	0·024	0·016	8·0		0·030	0·026	0·020	7·90	
7-3-34	0·030	0·024	0·024	7·80		0·030	0·026	0·012	6·8	
Total	0·590	0·432	0·280			0·562	0·294	0·420		
Average Silt contents.	0·029					0·028				

Note :—Samples of canal water obtained from four sites along the Nira Left Bank Canal were analysed as regards silt contents, in the soil research laboratory at Malegaon Colony near Baramati. Samples were taken at site 2 after a few hours after collecting sample at site No. 1, so that waters at site 1 could by that time reach site No. 2 This could of course be done only approximately. The same applied to samples at sites 3 and 4 also. Analysis has been given in 3 columns. The first column shows the total silt contents in the sample, pipetted off from a depth of 12 cms. below the water surface. No deposit takes place after the standard period of 4 minutes 48 seconds. Column 1 therefore shows total solids in suspension. Column 2 shows silt contents in the same after two hours, while column 3 represents the silt contents in the sample pipetted after 4 hours, the water being kept undisturbed.

The average diameter of silt s then found out by Stoke's law. Actual temperature of water was not observed but results have been worked out from usual temperatures obtained. The mistake, if any, will be negligibly small.

Similarly results of analysis showing total suspended silt carried by water of both the Nira Left and the Mutha Right Bank Canals for the year 1922 were published by Mr. D. V. Narayan Ayya, Assistant Economic Botanist, Bombay, Department of Agriculture, in his note on "The Aquatic Weeds in Deccan Irrigation Canals" appearing in the Journal of Ecology, Vol. XVI No. 1 for February 1928. Mr. Narayan Ayya writes as under :—

> "To get an accurate idea of the amount of suspended silt in two of these canals, we arranged to receive samples every week during the year 1922, from the Mutha Right Bank Canal, at Mile 1⅝ and Mile 8¼ and also from the Nira Left Bank Canal at Mile 2 and Mile 8. These canals were chosen because the Mutha Right Bank Canal has usually clear water and the Nira Left Bank Canal has usually silty water."

The table printed on the following page shows results of Mr. Narayan Ayya's analysis.

Statement giving silt contents in water of the Nira Left and the Mutha Right Bank Canals for the year 1922.

Note :—Figures in table show silt per cent by weight.

S. No.	Period.	Mutha Right Bank Canal.		Nira Left Bank Canal.	
		Mile 1.	Mile 8.	Mile 2.	Mile 8.
1	1- 1 to 8- 1-22	·017	·009	·021	·014
2	15- 1 to 22- 1-22	·017	·016	·018	·015
3	29- 1 to 5- 2-22	·010	·011	·014	·012
4	12- 2 to 19- 2-22	·010	·004	·018	·006
5	26- 2 to 5- 3-22	·009	·006	·020	·017
6	12- 3 to 19- 3-22	·010	·007	·007	·005
7	26- 3 to 2- 4-22	·011	·007	·016	·003
8	9- 4 to 16- 4-22	·009	·010	·023	·019
9	23- 4 to 30- 4-22	·010	·017	·021	·013
10	7- 5 to 14- 5-22	·007	·018	·011	·031
11	21- 5 to 28- 5-22	·013	·014	·029	·037
12	4- 6 to 11- 6-22	·004	·004	·014	·020
13	18- 6 to 25- 6-22	·003	·003	·021	·013
14	2- 7 to 9- 7-22	·008	·019	·016	·020
15	16- 7 to 23- 7-22	·024	·017	·020	·029
16	30- 7 to 6- 8-22	·026	·020	·045	·037
17	13- 8 to 20- 8-22	·037	·023	·033	·041
18	27- 8 to 3- 9-22	·029	·027	·024	·026
19	10- 9 to 17- 9-22	·020	·020	·030	·033
20	24- 9 to 1-10-22	·020	·018	·015	·019
21	8-10 to 15-10-22	·006	·003	·003	·007
22	22-10 to 29-10-22	·007	·007	..	..
23	5-11 to 12-11-22	·006	·008	·008	·006
24	19-11 to 26-11-22	·006	·004	·009	·007
25	3-12 to 10-12-22	·005	·005	·006	·004
26	17-12 to 24-12-22	·006	·006	·005	·006
27	31-12 to 7- 1-23	·006	·006	·005	·004

Mr. Narayan Ayya comments as under regarding the figures in this statement :

> "It will be seen that the Mutha Right Bank Canal carried decidedly less suspended silt on the whole than the Nira Left Bank Canal although the difference is not so marked as we were led to expect, nor is it absolutely uniform, there being occasions when the Nira Canal water contained less suspended silt than the Mutha. Two interesting facts are noticeable: (1) The great increase in suspended silt in both canals during the Monsoon (June to October) and (2) The great decrease in suspended silt in the three months following (October, November & December)."

To allow a comparison of silt contents in water in

(1) the river,

(2) the reservoir, and

(3) the canal,

samples were recently collected at (1) The confluence of Mula and Mutha rivers near Poona, (2) The Lake Fife at Khadakwala Dam across the River Mutha and (3) along the Mutha Right Bank Canal, during the period of floods in the month of July 1937, and analysed in the Irrigation Research Division Laboratory at Poona. The results were as under :—

Site.	Percentage Silt.
1. Mula and Mutha rivers at confluence.	0·034
2. Lake Fife	0·018
3. Mutha Right Bank Canal—(average of three sites).	0·017

Now comparing Mr. Talati's data with Mr. Narayan Ayya's data, for the N.L.B.C. the first difference that will be noticed is that the average silt per 100,000 shown by Mr. Talati is 29 parts, whereas the average by Mr. Narayan Ayya for the period from August to March will be found to be only about 12 parts per 100,000. The explanation is to be sought in the fact that in the year 1922, when Mr. Narayan Ayya collected and analysed the samples, the N.L.B.C. flowed continuously,

i.e., with closures only occasionally. In the year 1933-34 however, the canal was run by rotations, *i.e.*, there was flow in the canal for only 5 to 7 days in every 10 days rotation, while there was a complete closure for the remaining period till the canal opened again for the next rotation. In other words there were about 25 closures in the year 1933-1934 as against only about 4 in the year 1922. The result of this difference is very marked. The on-rush of waters on opening a canal in every rotation causes a definite increase in the suspended matter for the first few days. This is reflected in Mr. Talati's data. This also partly explains Mr. Narayan Ayya's finding No. 2, *viz.*, "The great decrease in the suspended silt in the months of October, November and December." Due to heavy demand in these 3 months the canal flows continuously with peak discharges with but little fluctuations, the suspended matter being small comparatively as a result. Another possible view would be that there was scour in the Nira L.B.C. when Mr. Talati collected his data in 1933 due to increase in discharge. The Author however believes that the former of the two views is correct or at least explains the main reason of the difference. This is corroborated by the fact that silt contents in January and February are larger than those in August and September, in Mr. Talati's data. In the former period closures are many while in the latter they were few and far between.

According to Mr. Narayan Ayya's figures the Nira L.B.C. carried on an average about 12 parts per 100,000 during the fair season, the maximum during monsoon being about 50 parts per 100,000 and the average for that season probably not more than 25 parts per 100,000. The average for the whole year may be said to be about 15 parts per 100,000. Mr. Talati gives data for 7 months only, but even judging by his figures the average silt contents for the period are 29 parts per 100,000. These figures may be compared with the silt carried in suspension by waters in alluvial canals. In the case of these latter the usual silt contents in canals are of the order of 100 parts per 100,000 (so far as the Author's information goes) while under flood condition the figure increases to 400 parts per 100,000.

The importance of results shown by Mr. Talati in his data lies in the analysis of the same given by him by determining first the total silt contents in the samples received and then also

determining the silt held in suspension by the water after being allowed to stand still for 2 hours and 4 hours respectively.

In the case of Upper India Canals, it is usual to measure total silt immediately after shaking and then that in a sample pipetted after the standard period of 4 minutes and 48 seconds. The difference of the two represents silt, the diameter of which is greater than 0·02 millimeter while the diameter of silt held in suspension after that period is less than 0·02 millimeter. In samples from Deccan Canals, no sedimentation, worth the name, takes place in this standard period, indicating that all silt is less than 0·02 millimeter in diameter. The diameter of particles remaining in suspension after two hours and after four hours is similarly determined by Stoke's law. The average diameter of silt in suspension at each of the four sites is thus determined from Mr. Talati's data and shows figures varying from 0·006 to 0·010 millimeter. It is to be noticed that average silt per 100,000 in the samples at the four sites agrees very closely though individual cases show differences—a fact which shows that analytical errors have cancelled each other. The fact that the percentage silt carried in canal mile 9 has not fallen down in the sample at mile 47 or at the intermediate sites is also important. The diameter of the silt particle held in suspension thus determined is also corroborated by direct observations under a microscope, found to be about 0·006 millimeter. The Author has not got figures of analysis with average diameter worked out for all silt in suspension for Upper India Canals, but would refer to data of Jamrao Canals in Sind which shows that 33% of the silt carried in suspension in that canal is larger in diameter than 0·02 millimeter, *i.e.*, such as could settle down in less than 5 minutes under steady conditions. The larger particles in suspension in the Jamrao are 0·2 millimeter in diameter though the percentage is small. Our samples on the other hand have no silt of diameter larger than 0·02 millimeter and this will explain the difference in conditions obtained on our canals and those in the alluvial canals.

Samples of actual material collected from the bed and sides of the N.L.B.C. have been taken at all the cross sections in Statements A and B printed in Appendix No. II. Fourteen out of these have been analysed at the Irrigation Research Division Laboratory at Poona by the Puri Siltometer. The results of analysis will be found in the Table printed overleaf.

Irrigation Research Division.

Silt analysis by Puri Siltometer for silt in Nira Left Bank Canal (Figures show percentage fraction to total silt by weight.)

Mile No.	Diameter.	Below ·08 mm.	·08—·1 mm.	·1—·2 mm.	·2—·25 mm.	·25—·33 mm.	·33—·5 mm.	·5—1 mm.	1—2 mm.	Above 2 mm.	Mean dia. above 2 mm.	Mean dia. excluding silt below ·08	Mean dia. including silt below ·08
5 7/8	Bed	29·7	29·67	5·52	27	0·27	2·32	3·78	0·38	Nil	Nil	0·204	0·154
	Side	3·37	15·60	0·77	59·8	0·94	11·4	5·34	Nil	Nil	Nil	0·255	0·248
11 7/8	Bed	36·93	2·07	8·94	4·04	4·93	4·06	8·2	11·12	10·62	2·84	1·086	0·660
	Side	47·90	0·817	3·91	0·649	1·04	0·209	4·48	6·92	34·2	3·7	2·71	1·433
12 1/2	Bed	42·32	3·05	22·44	3·77	5·99	2·64	6·2	7·6	5·925	2·58	0·672	0·403
	Side	70 03	8·3	6·7	0·30	0·50	1·77	1·50	2·74	8·80	3·2	1·18	0·388
15 5/8	Bed	33	1·51	8·61	1 67	2·13	0·87	4·03	8·90	39·8	3·68	2·45	1·66
	Side	87	2·558	9·172	0·99	0·48	0·14	Nil	Nil	Nil	Nil	0·164	0·055
19-3-70	Bed	18	2·7	12·6	5·5	7·7	2·57	4·57	9·76	36·58	3·2	1·73	1·425
	Side	72·6	2·86	16·2	1·70	0·50	Nil	5·0	Nil	Nil	Nil	0·264	0·099
24-3-510	Bed	17·64	·50	5·66	3·28	7·91	9·25	11·78	13·11	30·87	3·15	1·620	1·342
	Side	28·35	0·80	7·96	2·64	4·52	5·66	7·06	11·63	31·37	2·956	1·688	1·221
29-5-423	Bed	23·4	0·7	5·9	2·0	4·00	2·3	5·7	11·7	44·27	3·519	2·401	1·851
	Side	50·76	2·45	2·56	12·23	3·50	2·5	3·17	9·20	14·62	3·07	1·32	0·680
35-1-0	Bed	9	·5	7 1	3·4	8·2	14·7	9·1	9·	38·96	3·4	1·795	1·636
	Side	12	2·	11·	3·9	9·0	10·1	12·8	18·1	21·10	2·67	1·164	1·030
38-5-200	Bed	32·37	1·04	16·97	7·76	11·51	5·48	7·46	10·12	7·15	2·47	·716	·499
	Side	46·45	2·43	23·58	1·77	6·45	3·27	5·57	3·10	7·37	2·84	·694	·390
44-1-538	Bed	6	Nil	1·5	0·40	0·60	1·6	6·1	24·3	59·36	2·83	2·24	2 10
	Side	32	1·9	19·6	4·9	7·1	4·5	6·8	10·0	13·07	2·67	0·932	0·644
50-1-0	Bed	34	1·26	16·29	5·52	9·35	4·76	7·48	10·8	10·9	2·48	·865	0·586
	Side	89	1·34	7·48	·644	·296	·08	0·85	·10	Nil	Nil	·212	0·0585
54-5-200	Bed	32·07	2·0	20·37	4·97	10·69	4·81	7·67	10·41	7·00	2·252	·686	·478
	Side	64·44	13·00	20·45	·42	·51	·57	·38	·13	Nil	Nil	·146	·078
60	Bed	39·97	1·36	15·12	4·14	6·67	10·27	7·67	4·03	10·75	2·7	·839	·519
	Side	85·49	1·53	8·07	1·21	1·27	1·90	Nil	0·50	Nil	Nil	·106	·0495
64	Bed	19	2·7	5·1	1·8	3·4	·56	8·62	17·38	43·24	2·24	1·597	1·305
	Side	75	1·54	9·58	1·94	2·04	·26	2·8	2·15	2·95	2·96	0·714	·205

It will be noted from the analysis of these samples that they are by no means consistent with each other and have no comparison with the samples from Upper India canals. It must be explained that these samples are not necessarily all from banks or from soil cuttings. They were not particularly selected but these 14 were picked out at the Poona Laboratory by mere chance out of the large number (2 for each section in Statements A & B) of samples sent for analysis. Generally speaking, the samples in banks show a large percentage of particles less than 0·08 millimeter and consequently a smaller average diameter while those in murum cuttings show large diameters including pieces of sand and kankar. One meets with some percentage of particles having large diameter in bed in some bank sections also. This has to be traced partly to the high velocity cuts above these sections and partly to sand particles in soil and murum of which banks are constructed. Bed samples in murum cuts contain about 40 per cent to 60 per cent particles above 1 millimeter in diameter. The side samples contain on an average 50 per cent of silt below 0·08 millimeter. Some side samples show large percentage of particles above 1 millimeter. This is where the sections were in hard murum cuttings. Even black soil, it will be remembered, contains sandy particles and pieces of Kankar and this explains why soil cuttings show some particles of diameter above 1 millimeter, though the percentage is much smaller than in murum cuttings. An inspection of these large particles shows that the edges are sharp and not rounded like the sand met with in River and Nalahs. This fact is important as it shows that these particles have not rolled down along the river and the bed of the canal from the head works, but that they have fallen from the sides of rock and murum and also from soil cuttings. Even banks, it will be remembered, are provided with a casing of hard murum and there is nothing astonishing, therefore, if bed and even side samples in banks show some large diameter particles at places.

If one compares these results with those for Upper India canals, one will not fail to note the dissimilarity. In fact this dissimilarity is representative of the dissimilarity in the two types of canals and serves to demonstrate the extent to which conditions differ. The analysis of silt in the Jamrao Canals (Sind), *e.g.*, shows that there is no particle in bed (or side samples) larger than 0·25 millimeter in diameters except in one section at head of the Jamrao where maximum diameter is shown as 0·5 millimeter. Compare these with our bed samples

which on an average contains 25 per cent of silt larger than 2 millimeters and 35 per cent larger than 1 millimeter in diameter.

Any attempt to design the canal in such a manner as to transport these large particles as rolling silt, will need such steep slopes as cannot be possible or permissible in the design of Deccan canals. Nor is this necessary. If there is trouble regarding heavy sand or shingle being drawn into the canal at head works, the solution will be in choosing a proper site for the head regulator and not in allowing a steeper fall or a different shape to the channel.

The dissimilarity in side samples of silt too is as marked. The side samples for the Nira Left were collected not at the top of berm but rather at the junction of berm with the lower section. These samples therefore contain both berm silt as well as natural material at sides where berm was not well formed. That is why these samples are called side samples and not berm samples.

But leaving that apart, the dissimilarity in one detail is most important. In the case of the Jamrao Canals (Sind) the berm samples showed that its analysis compared favourably with the diameter of silt carried in suspension in the canal water. In Deccan there is no chance of this happening. For, we know that the diameter of average silt particle carried in suspension is 0·008 millimeter or thereabout, while the particles on berm have a definite visible size. The explanation of this is to be sought in the fact that the microscopic silt particles (0·008 millimeter in diameter) begin to gather together as soon as waters get into a zone of "no flow" but continue in a colloidal state so long as the waters are flowing. This phenomenon of flocculation takes about 2 days even under laboratory conditions when samples are kept undisturbed in a jar. Before that period each silt particle is seen under microscope as a separate body about 0·008 millimeter in diameter. Thence onwards they begin to form groups of 2 to 4 particles and these increase in number as days elapse. Silt seen under microscope after the sample is allowed to stand undisturbed for more than 2 days, is seen in floccules each about 0·03 to 0·1 millimeter in diamater. Deflocculating agents like sodium hydroxide cannot separate out these particles. This will explain the existence of silt particles larger than 0·1 millimeter in silt samples though the silt in suspension has diameter less than 0·01 millimeter. What was noticed in the laboratory conditions occurs

in actual running canals where water gets locked inside the grass on the berms. The microscopic silt is no more microscopic now, but is in regular floccules. The silt is definitely tenacious and particles do not deflocculate again.

It will be seen from a study of these samples for the Nira Left Bank Canal that the average diameter of the bed silt particles do not agree with the diameter indicated by the values of "f" as shown by the velocity or surface fall graphs. Determining "f_d" is therefore by no means an easy job as in alluvial tracts.

As already stated, the fact that silt carried by water in the Deccan Canals both during fair weather and in floods is microscopic, is extremely important. Even if the parts of silt per 100,000 were as small as 15 usually and about 40 in monsoon floods, but if the diameter of silt particles transported by the water were large enough, conditions about applicability of Lacey's theory to Deccan Canals would perhaps have been different. The action about silting in a flat graded portion of the canal would have under these circumstances been somewhat comparable with that in regular alluvial canals, but probably only about 1/7th as much in intensity. But due to the colloidal nature of the silt, deposition of silt on the bed or sides in a direct manner is impossible in the case of the Deccan canals, where deposition of silt is found to occur through the toppling over of overgrown silt berms.

The total quantity of water conveyed by the Nira Left Bank Canals in the whole year can roughly be estimated at about 10,000 M.cft. and even if the worst occurred, *i.e.*, if the whole amount of silt drawn in by the canal were deposited on the wetted perimeter and only "Aqua pura", *i.e.*, "H_2O" went out through the distributaries to the field, this would form a layer of only about 3/8 inch on the wetted perimeter in one year. This can happen only if water had absolutely no velocity. Actually in no length is the velocity in the N.L.B.C. less than 1·25 ft./sec. It takes about 1 hour for water to travel a distance of 1 mile. On the Nira L.B.C. we meet with murum cuts with rough sides and with narrow aqueducts where velocities vary from 2·5′ to 4′ per second. Such cuts and aqueducts are spread over at short distances of about 2 to 4 miles and the waters get completely churned up while passing through them. We have seen that even under laboratory conditions (no disturbance) the major portion of silt in canal waters remains in suspension even after 4 hours. There are therefore no

chances of any silt worth the mention being deposited even in low velocity sections by direct deposition. For, before they can do so, the silt particles are again churned over in these cuts and aqueducts. Even apart from the high velocity in narrow murum cuts, the very fact that the sides of these cuts have got a rugged surface, serves to create turbulence at the periphery which makes deposition of silt impossible, even on canals where murum and rocky cuts have the same velocity as in other lengths. The only condition very favourable to direct deposition of silt is when aquatic weeds grow wild on canal beds and sides and create practically "No flow" conditions for a small depth above the perimeter of the canal. It will be realized by observing the growth and toppling over of silt berms on Deccan canals that the source of the silt on the bed in normal sections is these very silt berms. The overgrown berm can no more resist the force of gravity and falls on the canal-bed. The lumps soon lose the tenacity when under water and the roots of grass die. This silt from the silt berms is quite different in nature from the material in the sand bars formed at the lower ends of high velocity cuts and aqueducts. The formation of these bars is similar to that of the sand and shingle bar formed below the head regulator of a canal except in magnitude. There is no canal in the Deccan starting from a pick-up weir which has not thus silted up in the head reaches of the canal particularly in the first mile or two. The Nira Left Bank Canal gets its quota of sand and shingle drawn in by the waters as they rush from the Vir Nalah at the head works of the canal with a velocity of from 5′ to 7′ per second through the head regulators. A sand bar of not less than 2·5′ in height has been formed as a result. A similar sand bar has got deposited on the Pravara Left Bank Canal and practically on every other known Deccan canal. As explained above similar sand bars also occur on a small scale at the lower ends of high velocity sections as, *e.g.*, the Malegaon cut in mile No. 39 of the Nira L.B. Canal. But they have nothing to do with the general design of the canal. The high velocity water in these cuts can drag certain sizes of sand and shingle along the bed and these must deposit as soon as the normal section is reached. No attempt to increase the slope of the canal or change the shape of the same is needed, as the sand bar is local and further deposition after reaching a certain height of hump is stopped automatically, the quantity required to be removed by manual labour being very small.

HYDRO-ELECTRIC POWER RESOURCES OF THE HYDERABAD STATE.

BY

NAWAB AHSAN YAR JUNG BAHADUR, C.E. (Cooper's Hill) M.I.E. (India), A.I.E.E.

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The object of this lecture is to state briefly the possibilities that exist in the Hyderabad State for the development of Hydro-Electric Power. The method adopted and the description of the various projects presented are of a preliminary nature. They are liable to alteration after the capabilities of each scheme are examined in detail with regard to catchment area, site of works, rainfall, run-off, and mineral, forestral, agricultural and other economic considerations.

Every Hydro-Electric Scheme is mostly dependent on rainfall and run-off. Variation of rainfall in different parts of the State is appreciable and departures from monthly and annual normals are also great. Hyderabad does not possess perennial streams with constant supplies throughout the year; and storage works have to be constructed if a continuous discharge has to be maintained for development of power. This generally entails heavy capital cost. A combination of irrigation and power therefore becomes a necessity, as cost of such storage works can be met by both undertakings. Many of the Hydro-Electric Power possibilities in the State are combined Irrigation and Power Schemes. Such combined projects are likely to pay better whereas they would not do so if confined to pure irrigation or power alone.

The first question that requires consideration is the rainfall and supply that can be depended upon from the catchment area of any project. The figures of discharge from catchment vary so considerably from year to year that a great deal of judgment is needed for determining the quantities which are capable

of being utilised whether for irrigation or for power. We have no recorded history of any river basin and in the absence of adequate data all that is possible is to work on an approximate rule; and even in applying such a rule, taking into account the particular conditions, judgment is the all important factor.

However, records are usually available of yearly rainfall at some stations situated within the catchment area, and it is only with the help of these figures that an attempt can be made to determine the dependable supply of any river basin. This is not as accurate as that determined from actual run-offs, but in the absence of any details, it is the only alternative. The method generally adopted is as follows. From the figures of the rainfall the yield every year is calculated according to Strange's Tables keeping in view the nature of the catchment area. Now placing these discharges in the order of magnitude it is noticed that at the two extreme ends there are freak figures. At one end we have very low figures which cannot be made the basis of design for economical utilisation; at the other end there are heavy discharges, the excess of which figures cannot be counted upon for the purpose of utilisation; their value is only to be taken as equivalent to the next lower figure.

The wide fluctuations being restricted in this manner, an attempt can now be made for arriving at a reasonable estimate of the dependable supply. A rough average of these figures is first obtained by omitting the freak bad years and by limiting all heavy discharges to the next lower figure (as mentioned above). After this a fresh set of figures, limiting all heavy discharges so as not to exceed the above rough average and the minimum figures to half that quantity, is made out. The average of these fresh set of figures is regarded as the dependable quantity utilisable, if the work is to be designed for purely irrigation purpose. But when a project is a combined Hydro-Electric and Irrigation Scheme, or even purely Hydro-Electric, it is necessary to take a more conservative figure and thereby a third average is determined. This average is regarded as the dependable supply on which the design of power schemes are to be based.

Next comes the question of storage needed for the economical utilisation of dependable supply. Hyderabad State, for a greater part of its area, depends on only one monsoon, extending for four months in the year namely from June to

September. In parts of Warangal, where there are two monsoons, no Hydro-Electric Schemes can be paying as they lie in close proximity to the coal-fields. During the South-West monsoon from June to September the rainfall is very precarious in the first half of June and whatever showers we do get is either quenched by the dry soil, the period being preceded by a hot summer, or it gets absorbed by the tanks in the catchment above. Some times there are showers in October as well, but these are usually small and cannot be relied upon for the purpose of fixing the storage of a power reservoir. It is evident that from the middle of June to the end of September one can expect the river to bring in enough run-off to feed the canals without being a draw on the storage. Storage is therefore needed for the remaining period of $8\frac{1}{2}$ months, which means that it should be equal to 17/24 or say 0·7 times the dependable supply that is proposed for utilisation. In addition to this a certain amount of storage is required as a reserve or carry-over to tide over years of scanty rainfall. Usually it is found that a bad year is succeeded and preceded by favourbale years, therefore this carry-over helps a great deal when the monsoon fails. For a power scheme it is considered that a carry-over of $12\frac{1}{2}$ per cent of the yield is not at all excessive. Therefore storage $= 0{\cdot}7 \times$ dependable supply plus $12\frac{1}{2}$ per cent carry-over (*i.e.*) $0{\cdot}825 \times$ dependable supply.

This is the storage that is to be provided about 6 inches above the full supply level of the canal which is necessary as the canal has to discharge the full capacity throughout the year and the supply in the reservoir below the F. S. L. of canal cannot be counted for utilisation. The 6 inches extra that has been allowed is to cover the driving head necessary to produce the required velocity in the canal.

Now comes the question of capacity of the canal to be determined at the head sluice and also that which will be available for the development of power at the turbines. In determining the capacity at the head sluice allowance has to be made for evaporation losses in the reservoir. From the results of various working tables showing the behaviour of reservoirs, prepared in the case of Tungabhadra, Upper Kistna, Bheema, Lower Kistna, Nizamsagar, Devanoor, Manair, etc., it is found that an allowance of 15 per cent can cover these losses. Of course

this cannot be made a hard and fast rule. It varies considerably according to the size of reservoir, its location, and the method of utilisation. Thus, for example, in large reservoirs like those on the river Kistna and its tributaries these losses may be as low as 10 per cent and for other smaller schemes they may be as high as 20 per cent. Therefore as a rough approximation an allowance of 15 per cent is considered sufficient. After deducting this quantity, the balance is to be taken as available to be drawn off as a continuous discharge throughout the year. Actually, the canal capacity has to be slightly bigger in order to meet the demands of peak loads. The peak load depends considerably on the use for which power is to be utilised. However, the allowance made for this purpose is based on the assumption that the average load will be about 50 per cent of the peak loads. From the discharge drawn into the canal at the head sluice certain deductions are to be made for losses in transit upto the forebay. These losses depend on the character of soils through which they pass and their length. Usually power canals are not more than 10 to 15 miles in length and they are likely to be either lined or kept in a good condition, therefore a deduction of 1/4 per cent per mile is considered sufficient to cover the losses in seepage, absorption, etc. Allowing these losses, the balance can be taken as the net discharge available at the turbines for the development of power.

In the ultimate development of power there is no doubt that all the schemes mentioned in this report are to be connected with each other, so that deficiency or break down of supply from any one source could be supplemented from other units. In view of such developments it is necessary to adopt some standards as it will be a great help in efficient working of the whole system.

The next question is whether alternating or continuous current is to be adopted. Except for small loads in residential areas, continuous current has very little application elsewhere. Most of the industries now-a-days utilise alternating currents. Alternating current is therefore preferred and in individual cases, where continuous current is required, it can always be obtained by installing suitable convertors. The great advantage alternating current has over direct current is the low cost of transmission and reduction in losses. Further, as most of

the industrial machinery is generally ordered from Great Britain, it will be convenient to adopt the British Standard practice for frequency and voltage. As regards the transmission it is suggested that 66 K.V. is to be the voltage of the main lines connecting the various units in the grid system. The maximum distance of transmission between any two units is about 130 miles and 66 K.V. transmission lines are considered sufficient for this purpose. The other branch lines to various industrial centres can be 22 K.V., 11 K.V , or of even lesser voltage according to the kind of load and distance of transmission.

In the absence of detailed investigation some basis are to be adopted, with regard to the various sub-heads of the estimate, in order to arrive at an approximate cost.

The cost of storage is an important item From experience in the State, it is found that earthen dams cost about Rs. 700 - per M.Cft. of storage, where the storage required is more than 2,000 M.Cft. It is therefore considered that an allowance of Rs. 750 - per M.Cft. is a sufficient provision to arrive at an approximate estimate of cost. Similarly for masonry structures the rate to be taken is about Rs. 1,100/- per M.Cft. and for storages of 25,000 M.Cft. or more a value of Rs. 650 - is sufficient. An intermediate value can be taken when the storage lies between 5,000 and 25,000 M Cft. Wherever the dams are partly masonry and partly earthen intermediate values are assumed according to needs of the particular case under consideration. Of course detailed investigation may give completely different values in each case, but as such determination is not possible due to want of information, the above values are considered as a sufficient basis for preliminary calculations.

With regard to the cost of canal works it is not possible to arrive at any rough guide on the cusec basis. Each canal has different characteristics. Some involve costly works such as tunnels, side walling, etc., whereas others may be going in a more or less balancing depth of cutting. Suitable values have to be taken in each particular case according to the difficulties that the canal has to negotiate. Wherever any preliminary details of the project are available the approximate values taken are assumed as more or less correct. In other places these difficulties have been judged from the information so far available and suitable values for cost are adopted.

As storage is created at a great cost, the valuable water leaving the turbines cannot be allowed to run to waste. Every effort is to be made to utilise these for the benefit of irrigation. Water is valuable whether it is in Telingana, Mahratwada or Carnatic areas; the only difference is that in Telingana the ryots are fully conscious of its value and make every effort to utilise it. In Mahratwada and Carnatic tracts the ryots are used to entrust their crops to nature and shirk the use of water for fear of payment of water rates. However it is only a question of time before the ryots of even Mahratwada and Carnatic will realise the immense advantages of a regulated supply to their dry and perennial crops, and once they are educated in this respect it is certain that they will clamour for it more than the Telingana ryots, as their lands are comparatively rich and a few waterings can considerably enhance the yield per acre. It is seen, therefore, that wherever perennial flow is created, it must be utilised for irrigation as far as practicable. The question remains—how to distribute the cost of storage between irrigation and power in the case of a combined scheme. This is arrived at on the value of a cusec for irrigation and power on the following basis.

The duties assumed at distributary heads for the different crops are :—

Crop		Acres in Cusec.		
1. Rice, Abi	..	60	Average from June to October.	
2. Rabi	..	150	Do.	Oct. to February.
3. Fodder	..	60	Do.	March to May.
4. Garden	..	120	Do.	June to January.
5. Fruit Garden	..	75	Do.	March to June.
		120	Do.	July to December.
6. Sugar-Cane	..	75	Do.	Jan. to February.
		60	Do.	March to June.
		120	Do.	July to December.
7. Rice, Tabi	..	40	Do.	February to May.

Allowing about 15 per cent losses the quantities required per acre at head sluice will be :—

1.	Rice, Abi	0·254 M.Cft.
2.	Rabi	0·100 ,,
3.	Fodder	0·152 ,,
4.	Garden	0·203 ,,
5.	Fruit Garden	0·314 ,,
6.	Sugar-Cane	0·433 ,,
7.	Rice, Tabi	0·312 ,,

In order to suit a perennial discharge the crops necessary in 100 acres of irrigation and their water requirements are :—

	Crops.	Acres.	Quantity Required In M.Cft.
1.	Rice, Abi	16	4·064
2.	Rabi	44	4·400
3.	Fodder	12	1·824
4.	Garden	11	2·233
5.	Fruit Garden	5	1·570
6.	Cane	8	3·464
7.	Rice, Tabi	4	1·248
	Total ..	100	18·803

Or say 18·8 M.Cft.

Now 1 cusec perennial is equivalent to 31·56 M.Cft. and therefore it is capable of irrigating 168 acres.

Coming to the question of returns, it is probable that the following net revenue is realisable :

16	acres	Rice, Abi	at	Rs. 11/- ..	Rs. 176-0-0
44	,,	Rabi	,,	,, 6/- ..	,, 264-0-0
12	,,	Fodder	,,	,, 4/- ..	,, 48-0-0
11	,,	Garden	,,	,, 15/- ..	,, 165-0-0
5	,,	Fruit Garden	,,	,, 20/- ..	,, 100-0-0
8	,,	Cane	,,	,, 35/- ..	,, 280-0-0
4	,,	Rice, Tabi	,,	,, 5/- ..	,, 20-0-0
100	acres				Rs. 1,053-0-0

DEDUCT.

Dry assessment @ Rs. 1/- per acre on Rice, Rabi, Garden, Fruit Garden and Cane lands	..	Rs.	84-0-0
Maintenance charges—			
Rice and Fodder @ Re. 1/- per acre	..	,,	28-0-0
Rabi @ Re. 0/10/0 per acre ..	..	,,	28-0-0
Fruit Garden @ Rs. 2/- per acre	..	,,	10-0-0
Cane @ Rs. 3/- per acre ..	..	,,	24-0-0
Total	..	Rs.	174-0-0
Revenue collection charges at 4 per cent on gross revenue	..	Rs.	42-0-0
Total deductions	..	Rs.	216-0-0
∴ Net Revenue ..	..	Rs.	837-0-0

Therefore a net revenue of Rs. 8·37 per acre is to be expected.

The revenue derived from irrigation is Rs. 1,400/- per cusec perennial.

Now if 'F' is the fall, the power generated per cusec will be $\frac{1 \times F}{15}$ K.W. If the net revenue after deducting maintenance charges, depreciation, working expenses, load factor, losses, etc., per K.W.H. is taken as $\frac{1}{4}$ of an anna, the value of 1 K.W. continuous will be Rs. 140/-. In Mysore State they assume a net revenue of B.G. Rs. 100/- per H.P. which means O.S. Rs. 155/- per K.W. continuous. Therefore the value of O.S. Rs. 140/-, if anything, is on the conservative side. Hence the net revenue derived from one perennial cusec is $\frac{140 \times F}{15} = 9{\cdot}3$ F. The charges for storage to be borne by power and irrigation are to be in the proportion of :—

Power : Irrigation as 9·3 F : 1400

or say F = 150.

Thus, for instance, if the fall is 200 ft., 4/7th the cost of storage will be brone by power and 3/7th by irrigation.

With regard to the electrical portion of the estimate the greater the extent of power generated the lesser will be the cost per unit. From actual quotations received in the case of Tungabhadra, Devanoor, Nizamsagar, etc., it is found that for an installation of about 30,000 K.W. continuous the cost is likely to be about B.G. Rs. 350/- per K.W., for 15,000 K.W. continuous B.G. Rs. 450/- and for 2,000 K.W. B.G. Rs. 600/-. This includes the cost of civil works, pipe line, standby plant, etc. In Mysore it is usually assumed at B.G. Rs. 300/- per H.P. which means about O.S. Rs. 460/- per K.W. (continuous). On the above basis suitable values are taken in each case. For transmission the cost has been based on actual quotations of Messrs. G.E.C. The value of 66 K.V. lines is Rs. 10,000/- per mile, of 33 K.V. line Rs. 5,500/- per mile, of 22 K.V. line Rs. 4,000/- per mile, and of 11 K.V. line Rs. 3,000/- per mile.

I shall now give a brief description of the several Hydro-Electric Schemes that can be developed in the State.

DEVANOOR PROJECT.

The Project is across the river Manjira a tributary of the Godavari.

The waters of this river are at present being diverted at two places. The first is at Ghanpoor in Medak District where an anicut has been constructed which diverts 234 cusecs in the right bank canal known as Mahboobneher for the irrigation of 8,504 acres, and 175 cusecs in the left bank canal called the Fatheneher which irrigates 5,246 acres. A little lower down in Nizamabad District, a large reservoir called the Nizamsagar has been constructed. This reservoir is expected to utilise 57,873 M.Cft. for the irrigation of 2,75,000 acres. Here the river has a drainage area of 8,376 square miles.

From somewhere near Bidar the river takes a long loop round one of the intervening ridges till it debouches into the Nizamsagar lake. The river first takes a south-easterly direction and reaching very near to Sangareddy (near Hyderabad) it turns to flow towards the north until it merges itself with the

parent river Godavari. It is this feature of the river that is proposed to be utilised in the Devanoor Project for the development of power. The proposal is to construct a reservoir a little below Bidar and tunnel through the intervening ridge, generate power and let the tail race drop into Nizamsagar.

The site selected for the Devanoor Project is situated 5 miles above Devanoor village in Bidar District. Here the river drains an area of 5,809 sq. miles. The average monsoon rainfall in the catchment is about 26·16 inches.

Working on the principle enunciated before, 51,910 M. Cft. is the supply that can be depended for the development of power. But in the case of Devanoor Project, large vested interests have come into existence in the lower reaches. There is the irrigation under Ghanpoor anicut and Nizamsagar reservoir that has got to be safeguarded which is predominantly rice and has a greater demand in Abi season than in winter or hot weather.

The project has, therefore, been designed for a utilisation of about 2/3rd of 51,910 or 34,600 M.Cft. However, there is a possibility that irrigation under Nizamsagar Project may one day develop to be of such a nature as to suit more nearly a perennial supply. In that case the project can negotiate the full dependable supply. This factor has been considered in the design by allowing a margin of 5 ft. between F.S.L. and M.W.L. and if in future the gates are raised to store waters upto M.W.L., the capacity then will be able to develop the maximum yield. The proposed storage for the utilisation of 34,600 M.Cft. of yield is 28,160 M.Cft. The dam has been roughly estimated to cost about Rs. 1·4 crores, which gives a a value of Rs. 500/- per M.Cft. The estimated cost of the channel is about Rs. 25,00,000 which includes Rs. 9,00,000 for the head sluice tunnel.

POWER POSSIBILITIES.

Power will be generated at three places. The extent of power generated is to be :—

1st drop.	7,392	K.W.
2nd drop.	7,344	,,
3rd drop.	3,050	,,

Total 17,786 or say 17,800 K.W. continuous. The total cost of generation @ Rs. 450/- per K.W. continuous is to be Rs. 80 lacs.

When the full storage development takes place, the extent of power generated will be about 26,700 K.W. continuous.

FINANCIAL ASPECTS.

(*a*) *Cost of Storage*	Rs.	140 lacs.
Cost of canal	Rs.	25 ,,
Total Cost of Civil Works ..	Rs.	165 lacs.
(*b*) *Cost of Generation*	Rs.	80 lacs.
Cost of main transmission lines (300 miles)	Rs.	30 ,,
Cost of subsidiary transmission lines	Rs.	5 ,,
Total Cost of Electrical Work ..	Rs.	115 lacs.

Total cost of the scheme—Rs. 280 lacs.

Net revenue realisable on 17,800 K.W. at Rs. 140 per K.W. continuous will be Rs. 24·92 lacs.

Therefore Returns 9 per cent.

CONCLUSION.

The great advantage this project has is in its location. It is situated almost near the centre of Hyderabad State. It is close to the Capital where there is already a developed load. Hyderabad, Nander (*via* Nizamabad) and Shahabad (*via* Gulburga) are 60, 120 and 100 miles away respectively. Pumping if necessary from the water logged areas under Nizamsagar Project is also expected to consume a fair amount of power. Considering these factors the project appears to be a proposition that will develop very quickly and attain the expected realisations rapidly. There are also bauxite deposits in Bidar District which, if developed, will take away a bulk of this power for the manufacture of aluminium. All these factors combined together make this project a very attractive proposition.

NIZAMSAGAR PROJECT.

The largest irrigation scheme that has been constructed in the State is the Nizamsagar Project. A masonry dam 112 ft. high above the river bed is built across the Manjira river. The river at this point drains 8,376 square miles of area. The flood disposal works are capable of dealing with a discharge of 525,000 Cft. per second. The waters of this lake are spread over an area of 56 square miles and the quantity that is stored is 29,700 M.Cft. The Nizamsagar Canal is 100 ft. wide and 10½ ft. deep in the upper reaches; and carries a discharge of 3,400 Cft. per second. The main Canal is 72½ miles long and is designed to irrigate 275,000 acres. The project was completed at a cost of Rs. 447 lacs. It was started in 1924 and water was first let out for irrigation in 1930.

In the first reach of the canal, upto Narwa acqueduct, the bed level of the canal is dropped at three places *viz.* at Chainages 14, 21 and 32 and the drops are 10·5 each. It is proposed to utilise these drops for the development of power. Being situated close to each other, it is quite possible to concentrate these drops into one development.

The total fall available is 31½ ft. There is also a possibility of combining the variable head of the reservoir itself.

It is proposed to construct another reservoir higher up where the river has a drainage of 5,809 sq. miles. This is the Devanoor Project just discussed. From this reservoir it is expected to let down a continuous discharge of 950 cusecs into Nizamsagar lake from the tail race of the turbines. The catchment between the two reservoirs can be depended upon for at least another 400 cusecs. If the irrigation under Nizamsagar Project develops into a more perennial type, a utilisation of 1,350 cusecs perennial will not be a difficult question. 1,350 cusecs dropped 31½ ft. will give more than 2,800 K.W. continuous. Most of the civil works needed have already been constructed and what is required now is a small power channel to discharge 1,350 cusecs, generation sets and transmission lines.

It is expected that the power channel will not cost more than 1·3 lacs as it is hardly 20 chains long. The generating sets at Rs. 600/- per K.W. continuous will cost Rs. 16·2 lacs and the

power is to be transmitted to Nizamabad *via* Bodhen on the north and Devanoor power station on the west. The distance of transmission is likely to be 75 miles and at Rs. 10,000/- the cost of transmission will be Rs. 7·5 lacs.

The total cost of the scheme will be about Rs. 25 lacs and a net revenue of Rs. 3·92 lacs can be easily anticipated. The return will be 15·6 per cent. The returns are exceptionally good because it is not burdened with any cost of civil works, these being already executed. The project is remunerative and is well worth taking up with the Devanoor Project, without which its development will be considerably reduced.

The cost of both these schemes that is Devanoor and Nizamsagar will be Rs. 305 lacs and the total power generated 20,600 K.W. continuous. The above schemes combined will give a return of 9·46 per cent.

TUNGABHADRA PROJECT.

The river Tungabhadra, one of the large tributaries of the river Kistna, rises in Mysore State, and forms the boundary between Hyderabad and Madras in its last reach of 192 miles before joining the parent stream, the Kistna.

The waters of the river are at present being diverted by numerous anicuts for purpose of irrigation. The biggest system is the Kurnool Cuddapa Canal in Madras Presidency, which commands an area of 357,000 acres. Schemes for more effective utilisation of this river have been under consideration for a long time. The Government of Mysore are proposing to construct a reservoir at Lakkavalli on its tributary, the Bhadra. The Governments of Hyderabad and Madras are considering the feasibility of a joint reservoir scheme near Mallapuram in Hospet Taluq of Bellary District. Because of the different interests involved, the apportionment of shares has become a complicated problem. It is, however, hoped that the matter will soon be decided by mutual agreement.

The river Tungabhadra after descending the slopes of Western Ghats in Mysore State takes up a gentle fall till it reaches Valvahapur a little above Mallapuram. From here it starts descending into rapids and falls over 300 ft. in 34 miles.

Due to this feature and due to the favourable configuration of the country, the Hyderabad Canal taking off from the Mallapuram reservoir can be made to drop nearly 230 ft. without any appreciable loss of command; the drop in terms of energy is a tremendous asset to the Project as well as to the country.

The project briefly comprises of:—

1. Construction of a joint reservoir near Mallapuram.
2. Construction of irrigation canals on either side.
3. Development of power on the Hyderabad side.

The dependable supply of this river at Mallapuram has been a subject of controversy for a long time. Joint gauging operations were conducted at the anicuts of Valvahapur and Sunkesala in order to calibrate the gauge readings. The result of these operations is that the dependable supply lies in the region of 336,000 M.Cft.

The site selected for the reservoir at Mallapuram is really an ideal site. The river here cuts through a barrier of hills. There is sound rock exposed in the river bed.

It is expected that Hyderabad will be able to draw a perennial discharge of 2,500 cusecs from its share of the waters and it will be possible to generate 38,000 K.W. continuous at the two drops aggregating to 230 ft. The cost of power generation at Rs. 350/- per K.W. would be about 133 lacs. The power will have to be transmitted to Hyderabad, Hutti, Raichur, Gulburga, Yadgir, Shahabad, etc. The total distance of main transmission will be about 400 miles and at Rs. 10,000/- per mile, the cost of transmission will be Rs. 40 lacs. Besides this, Rs. 7 lacs are provided for subsidiary transmission lines.

The cost of both the irrigation and power project is likely to be:—

1.	Cost of storage	..	Rs. 230	lacs.
2.	Cost of Canal system	..	„ 615	„
3.	Cost of generation	..	„ 133	„
4.	Cost of transmission	..	„ 47	„
	Total	..	Rs. 1,025	„

The net revenue will be :—

1. From irrigation 2,500 cusecs at Rs. 1,400/- per cusec.	..	Rs.	35 lacs.
2. From power 38,000 K.W. at Rs. 140/- per K.W.	..	„	53 „
Total	..	Rs.	88 „

Therefore the returns will be 8·6 per cent.

From the figures given above, it will be seen that power makes all the difference in converting the scheme from a protective to a productive project. The protection that this project will afford to a large area of this State, which suffers contsantly from the vicissitudes of seasons, are so apparent that they need not be emphasised here. Raichur, though it lies in the doab of two large rivers of the Deccan, has got to go thirsting for water many a year and watch at the same time tremendous quantities running to waste in the seas. This project is proposed to harness one of these in order to give some security to life in this part of the country. Fortunately for Hyderabad the Project incidentally gives such an asset in the shape of power that any investment on it will be well worth the money.

KADDAM PROJECT.

Kaddam river, a tributary of the Godavari, rises in Boath Taluq of Adilabad district. After traversing for a distance of 26 miles from its source, it starts falling in a series of rapids and within 4 miles it drops about 400 ft. in its command of level; the maximum concentrated fall at one place being 170 ft. locally known as Somanakundam falls dedicated to the deity of Somannale whose shrine is carved in the nappe.

The scheme consists of harnessing the Kaddam river at Kuntala, supplemented by the supplies from Gundi Vagu and Nagamalliah streams. Thus, in all, it is proposed to utilise about 353 sq. miles of drainage. The average monsoon rainfall in this locality is 36·26″. The supply that can be depended upon for the development of power from the river Kaddam

itself, is estimated to be 4,043 M.Cft., which gives a yield of 15·8 M.Cft. per sq. mile. Treating Gundi Vagu and Nagamalliah in a similar manner we get the total supply as 5,576 M. Cft., and the storage has been estimated to cost about Rs. 47 lacs in all.

In the canal, it is expected that there will not be much loss in seepage, as the length is very small and most of it will be lined. The discharge available at forebay for the development of power is 148 cusecs continuous. Roughly it is estimated that the canal works will cost about Rs. 6 lacs in all.

Power Possibilities—The total fall available from the forebay to the river bed is 405 ft. of which 390 ft. will be available for the generation of power. The extent of power generated will be :—

$$\frac{148 \times 390}{15} = 3{,}848 \text{ or say } 3{,}850 \text{ K.W. continuous.}$$

The total cost of generation sets at Rs. 500/- per K.W. continuous will be Rs. 19·00 lacs. A lump sum of Rs. 5 lacs is provided for transmission lines, as it is expected to utilise this power nearby for the development of alloy steel industry.

FINANCIAL ASPECTS—

Total cost of storage	.. Rs. 47 lacs.
Cost debitable to irrigation	.. „ 13 „
Cost debitable to power	.. „ 34 „

(*a*) *Cost of Power Scheme.*

Cost of storage	.. Rs. 34 lacs.
Cost of canal works	.. „ 6 „
Cost of generation	.. „ 19 „
Cost of transmission	.. „ 5 „
Total	.. **Rs. 64 lacs.**

Power granted=3,850 K.W. continuous.

Net revenue realisable ..	Rs. 539,000/-
Returns ..	8·42 per cent

(*b*) *Cost of Irrigation Scheme.*

Cost of storage ..	Rs 13 lacs.
Cost of canal works ..	20 „
Total ..	Rs. 33 lacs.
Irrigation proposed ..	23,500 acres.
Net revenue realisable @ Rs. 8·37 per acre ..	Rs. 197,000
Therefore, Returns ..	5·91 per cent

(*c*) *Combined Scheme.*

Total cost of project	Rs. 97 lacs.
Net revenue	„ 7·36 „
Returns	„ 7·6 „

Conclusion:—This project appears to be fairly remunerative. There are large deposits of rich iron ore in the neighbourhood of this project. In case a steel industry is established here, this project is well worth consideration.

PURNA PROJECT.

The river Purna rises in the plateau of Aurangabad near Gouthala village of Kannar Taluq. After a winding course of nearly 250 miles, it joins the parent river Godavari near Kanteswar. Except for a small length of about 20 miles, where it runs through the Buldana district of Central Provinces, it mostly follows its course in Hyderabad State. In the upper reaches the river has a very gentle fall and flows between well defined banks composed of either black or fine alluvial soil.

The waters of this river are at present running to waste, there being no utilisation either for irrigation or power. In this scheme, it is proposed to harness it for power and the tail waters will be picked up by an anicut for irrigation.

The river from about 10 miles below the crossing of Jalna —Buldana road enters into a hilly tract and emerges out into plain country near Aundah in Parbhani district. It is in this reach that it offers many suitable sites for storage. Further, taking advantage of two loops in the river course between the villages Yeldari and Digras and also by keeping the cill high, a fair amount of power can be developed.

The scheme comprises of :—

1. An upper storage reservoir with a masonry dam.
2. A power channel at the left flank to be taken along the hills and dropped 120 ft.
3. A pick-up dam.
4. A low level channel from the pick-up dam to irrigate about 200,000 acres.

At the site of upper storage, the river drains an area of 2,800 sq. miles. The average monsoon rainfall is 26·16 inches. The dependable supply has been calculated to be about 17,145 M.Cft. The storage needed for its utilisation is 14,144 M.Cft., or say 14,200 M.Cft., the reservoir capacity below cill is 2,700 M.Cft., and the gross storage needed is 16,900 M.Cft. The site at Sawangi is in a narrow gorge. The cost is not likely to be more than Rs. 400/- per M.Cft., on this basis the cost of reservoir will be Rs. 67·6 or say Rs. 68 lacs.

The lower storage at pick up dam will be about 2,500 M. Cft. and is roughly estimated to cost about Rs. 20 lacs.

The dependable supply proposed to be utilised is 17,145 M. Cft. Deducting 15 per cent for losses in evaporation, the balance left over will be 14,573 M. Cft. which represents a perennial discharge of 467 cusecs. The power channel is only 6 miles long and further it will be mostly lined as it has to be taken on the side slopes of the hills. The cost of this power channel at Rs. 250/- per cusec-mile, inclusive of lining, will be Rs. 7·0 lacs. Besides

the power channel there will be an irrigation channel 50 miles long. The discharge at head sluice will be 450 cusecs. The cost of channel and distributaries at Rs. 150/- per cusec-mile will be Rs. 33·75 or Rs. 34 lacs.

The maximum drop available is 120 ft., and with a perennial discharge of 467 cusecs it is possible to generate 3,740 K. W. continuous. The cost of generation at 500 per K. W. will be Rs. 20 lacs. The power can be transmitted to Nander, Parbhani and Jalna. At Nander it will be connected with the Devanoor system. The total distance of transmission will be 128 miles. As the maximum distance is not more than 64 miles, a 33 K.V. line is advisable. This at Rs. 5,500/- per mile will cost Rs. 7 lacs.

The discharge that is to be let down from the tail race of the turbines is 467 cusecs. This has to traverse about 25 miles before it is picked up for irrigation. Allowing about 17 cusecs for losses in transmission, the amount of water that will be diverted in the irrigation canal will be 450 cusecs. A discharge of 450 cusecs perennial is capable of irrigating 75,000 acres yielding a net revenue of Rs. 6·28 lacs.

FINANCIAL ASPECTS.

Total cost of storage	..	Rs. 68 lacs.
Cost debitable to irrigation	..	,, 30 ,,
Cost debitable to power	..	,, 38 ,,

(*a*) *Cost of Power Scheme.*

Cost of storage	..	Rs. 38 lacs.
Cost of canal works	..	,, 7 ,,
Cost of generation	..	,, 20 ,,
Cost of transmission	..	,, 7 ,,
Total	..	Rs. 72 lacs.

Power generated	..	3,740 K.W. continuous.
Net revenue realisable at Rs. 140/- per K.W.	..	Rs. 5 24 lacs.
Returns	.	7 27 per cent.

(*b*) *Cost of Irrigation Scheme*

Cost of storage.		
(i) Upper reservoir		Rs. 30 lacs.
(ii) Lower pick-up reservoir	..	„ 20 „
Cost of canal works	..	„ 34 „
Total	..	Rs. 84 lacs.

Irrigation proposed	..	75,000 acres.
Net revenue realisable at Rs. 8·37 per acre	..	Rs. 6·28 lacs.
Returns	..	7·47 per cent.

(*c*) *Combined Scheme.*

Total cost of project	..	Rs. 156 lacs.
Net revenue	..	„ 11·52 lacs.
Returns	..	7·4 per cent.

This scheme has a great advantage in the fact that it is closely situated to the cotton centres of the Hyderabad State. Nander is hardly 40 miles away, Parbhani 24 miles and Jalna 64 miles. Water power, if developed here, will be absorbed by these industrial centres. The market is more or less fully developed and anticipated returns will be realised almost with the completion of the works.

MANAIR PROJECT.

The Manair which lies in the Godavari basin rises in the Thirmalapur hills and joins the parent river after coursing for 140 miles through the districts of Nizamabad and Karimnagar. The waters of this river are at present being used only for irrigation of small areas from open head channels.

Briefly the Project consists of :—

(a) A reservoir across the Manair.

(b) A power lined channel 6¾ miles long with a carrying capacity of 135 cusecs.

(c) An irrigation channel 17 miles long with a carrying capacity of 115 cusecs at the Upper Reach.

(d) An irrigation of 9,200 acres.

(e) Generation of electrical energy to the extent of about 680 K.W. continuous by dropping the canal 120 ft. into Mallareddypet tank.

The catchment area of the river at the site of the dam is 836 sq. miles, of which 537 is intercepted and 299 free.

The reservoir is formed by a dam 86 ft. high above the deepest founds and has a gross capacity of 3,022 M.Cft. and effective capacity of 2,462 M.Cft. The dam will be Ogee overfall type in the river section capable of discharging a flood of 182,037 cusecs.

Below this reservoir the river descends into rapids falling as much as 207 ft. in 6 miles. It is this that has been utilised for the development of power. A power channel has been taken on the left flank, which after a length of 6¾ miles drops through 120 ft.

The project has been estimated in detail. It is to cost Rs. 30 lacs without any power development and Rs. 37·3 lacs with power development. It is expected that a net revenue of Rs. 226,675/- will be realised from irrigation and Rs. 95,200 from power. The project as a purely irrigation scheme will give a return of 7·55 per cent and 8·65 per cent. as a combined irrigation and Hydro-Electric Project.

The power developed is not very much, but still as a combined scheme it is well worth consideration. The power can be connected with the Nizamsagar power station or with Nizamabad and it will do its share in contributing to the Grid system.

PENGANGA PROJECT.

This river rises near Buldana in the Province of Berar and from just near Basim it flows along the boundary of Hyderabad State, right down till it joins the Wardha river near Chanda.

The river Penganga falls through a height of 120 ft. near Islahpur midway between Hadgaon and Kinwat. These falls are known as Shasrakund falls It is proposed to harness this fall for the generation of Hydro-Electric Power.

The river appears to offer a very suitable site for storage. The catchment area of the river at this site is 3,000 sq. miles and treating it as a similar catchment to that of Purna, which is close by, we can expect a discharge of 500 cusecs. The channel taking off on the right flank is to be carried for a distance of nearly 35 miles and dropped in the river bed; a fall of about 210 ft. is available here The total power to be generated is 7,000 K.W. continuous. The waters from the tail race are to be picked up by an anicut near Kinwat and made to irrigate lands in Adilabad District.

The project is to give 3,500 K.W. and irrigate about 40,000 acres, and is likely to cost about Rs. 125 lacs in all.

GODAVARI PROJECT

The river Godavari is one of the two main rivers that drain the plateau of the Deccan. The river starting from the western ghats flows for a distance of 83 miles through Bombay Presidency. After this it forms a boundary between Hyderabad and Bombay for 64 miles and then flowing for 432 miles through the State it forms a boundary between Central Provinces and Hyderabad for 42 miles and between Hyderabad and Madras for 134 miles before it enters the Madras Presidency, where after another 94 miles, it falls into the Bay of Bengal. The river drains in all 121,500 sq. miles of catchment and of this 48,000 sq. miles are contributed by the Hyderabad State.

It is proposed to harness this river by constructing a reservoir at a site where it has a catchment of 42,500 sq. miles. The bed here is rocky and economical design is feasible. It is possible to get an effective storage of about 46,000 M.Cft., which

roughly works out to 1 M.Cft. per sq. mile. The capacity compared to the yield is very low with a large river like Godavari and it is expected that it will be possible to utilise at least 2 loads, if not more. The utilisation will therefore be in the region of 100,000 M.Cft. Deducting 15 per cent for losses in evaporation the balance available to be drawn off will be 85,000 M.Cft. which represents a perennial flow of 2,700 cusecs.

A canal taking off on the left flank will give a drop of nearly 275 ft. after its 30th mile and if it is taken for a distance of another 5 miles a further drop of 125 ft. can be created. The total drop available will be 400 ft. The water from the 2nd drop can be picked up by an anicut and joined by the waters from the Kaddam power station, a combined canal taken round the hills for the irrigation of perennial crops.

The losses in the power channel 35 miles long having a discharge of 2,700 cusecs, at the rate of $\frac{1}{4}$ per cent per mile, will be roughly 250 cusecs. The net discharge available for power development will be 2,450 cusecs which, dropped through a height of 400 ft., will develop 65,000 K.W. continuous.

The cost of the combined project is likely to be :—

1.	Cost of storage. 52,600, M. Cft. @ Rs. 650/- per M. Cft.	..	Rs.	340 lacs.
2.	Cost of Power Channel. 35 miles @ Rs. 2 lacs per mile	..	,,	70 ,,
3.	Cost of Irrigation Channel. 100 miles long @ Rs. 1·5 lacs per mile	..	,,	150 ,,
4.	Cost of generation. 65,000 K.W. @ Rs. 350/- per K.W.	..	,,	230 ,,
5.	Cost of transmission lines. 400 miles @ Rs. 20,000/- per mile 66 K.V. Double circuit lines	..	,,	80 ,,
	Total		Rs.	870 lacs.

Say Rs. 9 Crores.

The revenue realisable will be :—

1. Irrigation.				
2,450 cusecs at Rs. 1,400/- per cusec	Rs.	34·0	lacs.
2. Power.				
65,000 K.W. at Rs. 140/- per K.W.	„	91·0	„
Total ..	Rs.	125·0	lacs.
Returns.		13·9	per cent

This project is likely to prove very remunerative. The amount of power generated is so large that, unless some potential industries like steel or aluminium is established, it will not be worth while taking up the scheme. There are extensive deposits of rich iron ore on the banks of the Godavari and if these are worked on a large scale, the Godavari Project is a most paying proposition.

LOWER KISTNA PROJECT.

This project is for harnessing the river Kistna, after its junction with its tributaries, the Bheema and the Tungabhadra. Shortly after its junction with the Tungabhadra, the Kistna has cut its gorge for nearly 100 miles through the Amarabad-Nallamàli plateau. Beyond, the high and impenetrable Nallamali range, with its flanking member, the Bellamkonda ridge, extends right up to Pulichinthala. This dividing line of the Kistna catchment runs very close to the river channel, deflecting its course in a north-easterly direction. Towards the north of the Hyderabad side, the valley is of fairly considerable width, the drainage from which finds its way into the Kistna through the tributaries known as the Dindi, the Pedda Vagu, the Hallia Nadi, the Musi, the Paleru and the Muneru.

At the site selected for the reservoir at Yelleshwaram, the bed is flat with high precipitous hills on either side over 600 ft. in height. The nature of the rock in the river is composed of one continuous sheet of apparently unfissured gneiss. The hills rise so precipitately that the only alternative to pass the surplus is over the dam itself. The rock being sound it is expected that with a suitable design there will be no erosion below with a fall of 400 ft. over the dam.

In the design of lower Kistna Project, it is necessary to obtain a reasonably clear idea of the extent to which water is likely to be diverted by the Upper States. The interests involved are so numerous that it has become a very complicated problem, especially in the absence of adequate data for yield and run-off. Records are available of the yields of the Kistna at Bezwada and of the Tungabahdra at Sunkesala and Valvapur; with this meagre information an attempt has been made to arrive at the supplies available at Yelleshwaram for apportionment between Hyderabad and Madras.

From the figures of yield at Bezwada anicut it can be said that the dependable supply of the Kistna at Bezwada lies in the region of 11,00,000 M. Cft. Deduction has first to be made for the catchment of about 17,500 sq. miles lying between Bezwada and Yelleshwaram sites. Next we have got to reserve for works of a minor nature that will eventually be carried out in the catchments and which we will not be able to prevent. Allowance has also to be made for works on the smaller tributaries of the river Kistna as these bigger schemes cannot be made to stop such developments. After these deductions we will arrive at the ultimate dependable supplies in the major tributaries and the parent river. In these waters four different Governments are interested *viz*. Bombay, Mysore, Madras and Hyderabad. Unless a comprehensive survey of the possibilities in these different States is made, it is difficult to say exactly what supplies will be allotted to Lower Kistna Project. However, it is roughly estimated that inclusive of seepage about 450,000 M. Cft. will be available as the share of Lower Kistna after making deductions for the various interests mentioned above.

Irrigation under Lower Kistna Project will be predominantly rice. Further the supplies from the upper reservoirs will come in mostly in a regulated manner and also a good deal of water will be received by this reservoir in the non-monsoon period owing to seepage from upper works. Due to these factors, it is considered that this reservoir will quite easily manage a utilisation corresponding to about 4 loads which means that it should have an effective capacity of at least 120,000 M.Cft. In addition to this a certain amount of reserve is necessary in order to meet the demands of irrigation in the early part of the monsoon, as the river supply will be somewhat delayed. It is therefore proposed to have an effective

capacity of about 140,000 M.Cft., which will suffice to meet the full requirements of irrigation under this project. There will be very little submergence of cultivable lands. The dam has been approximately estimated to cost Rs. 1,050 lakhs and for a gross storage of 206,000 M.Cft. it gives a value of Rs. 500/- per M.Cft. of storage.

The cost of the canal works is approximately estimated to be Rs. 12 crores. From the Hyderabad share of the waters it is proposed to irrigate 900,000 acres about the same as that in the Kistna Delta.

From the discharge to be let down in the bed of the river, for the Kistna Delta Irrigation, it is proposed to develop power. The available drop is about 250 ft. The extent of power generated will be 50,000 K.W. continuous. The cost of generation at Rs. 350/- per K.W. will be Rs. 175/- lacs. This power will be connected to Hyderabad on one side and to Tungabhadra power station on the other. The total distance of transmission lines will be 300 miles. It is proposed to have a double circuit 66 K.V. lines costing Rs. 20,000/- per mile. The total cost of transmission will be Rs. 75 lacs which includes Rs. 15 lacs for subsidiary lines.

The total cost of the scheme will be :—

Cost of storage	..	Rs.	1,050 lacs.
Cost of canal works	..	„	1,200 „
Cost of generation	..	„	175 „
Cost of transmission	..	„	75 „
Total	..	Rs.	2,500 lacs.

The receipts will be :—

From irrigation 900,000 acres at Rs. 8·37 per acre	..	Rs.	75 lacs.
From power 50,000 K.W. @ Rs. 140/- per K.W.	..	Rs.	70 „
From safeguarding delta irrigation 900,000 acres at Rs. 2·79 per acre		Rs.	25 „
Total	..	Rs.	170 lacs.

Therefore, the return will thus be 6·8 per cent.

The project is fairly remunerative and will pay a return of 6·8 per cent on the capital outlay. The district of Nalgonda, which the canal will feed in its early reaches, is of ten visited by famines. This work once executed will be a great boon to the ryots of of this district. The cost involved is of course large as much as Rs. 25 crores, but the irrigation and power possibilities are also great. On a formidable river like the Kistna in its lower reaches the Project has to be of such a magnitude if it is contemplated to utilise its full possibilities. However, as to when this Project should be started is a question to be settled with the Government of Madras and therefore this is considered as one of the last schemes to be taken up in the programme of Hydro-Electric Development of the State.

UPPER KISTNA PROJECT.

The river Kistna takes its rise near Mahableshwar some 4,000 ft. above sea level. It drains at its source about half the length of bountifully rain fed Western Ghats lying between the latitudes of Bombay and Mangalore where the rainfall is as high as 225 inches. From the Ghats, it flows for a distance of nearly 350 miles through the Bombay Presidency and then entres the Dominions of Hyderabad. The Kistna river on entering the Dominions, descends some 250 ft. within a distance of 10 miles. The steep drop aggregates to 132 ft. within 2¾ miles which are locally known as Jaldurg falls.

The site selected for reservoir is just above the rapids. The drainage area at the site of the dam is 18,426 sq. miles of which 2,114 sq. miles constitute the Ghat portion. The gross capacity of the reservoir is 63,675 M. Cft. and the net capacity is 56,027 M. Cft. above the cill of canal.

Unfortunately no records of discharges are available of the river Kistna in the neighbourhood of this site. There are a few records of its higher reaches, but even those are incomplete. In order to get an approximate idea of the capacity of this river a comparison has been drawn up with the Tungabhadra river in a year of bad rainfall. The discharge of the Tungabhadra at Mallapuram in 1918—1939, a year of scarcity, was 208,065, and that of the Kistna 314,963 M. Cft. It is therefore assumed that the dependable supply of the Kistna at the site will be 1⅓rd

times that of the Tungabhadra at Mallapuram. This also roughly corresponds to the figures at Bezwada anicut. The dependable supply of the Tungabhadra at Mallapuram as shown under the Tungabhadra Project is 336,000 M.Cft., that of the river Kistna will therefore be 449,000 M.Cft.

Two canals will take off from the reservoir, one on each side. It is proposed to drop the right bank canal about 225 ft. in order to meet the Tungabhadra canal. The joint canal will then be taken to Raichur and Gadwal. The perennial discharge in this canal will be about 2,500 cusecs at the head sluice, allowing for losses on the way and consumption for the first reach it is expected that about 2,000 cusecs will be available for the development of power. This, dropped through a height of 225 ft., will give 30,000 K.W. continuous. The total area commanded by this canal is 575,937 acres.

The left bank canal will be mostly seasonal. It commands an area of 11,23,075 acres of which 198,978 acres lie in Bijapur district of Bombay Presidency. It is proposed to irrigate about 800,000 acres under both the canals.

The power that will be generated is practically situated within the gold area. It has practically the same market as that of Tungabhadra. The question of its generation entirely depends on the increase of demand in the Tungabhadra zone. It is when gold fields are developed on an extensive scale that the Hydro-Electric possibilities of this project may be utilised. There are copper mines near the junction of the Tungabhadra with the Kistna and if this industry develops, large amount of power may come in for demand.

The cost of the scheme will be approximately as follows :—

Cost of storage	..	..	Rs.	300 lacs.
Cost of canal system	..	..	„	1,000 „
Cost of generation.		..	„	105 „
Cost of transmission	..	..	„	45 „
	Total	..	Rs.	1,450 lacs.

Revenue for irrigation	.. ..	Rs.	66·96	lacs.
Do. power	.. ..	„	42·00	„
Total	..	Rs.	108·96	lacs.

Therefore the returns will be 7·5 per cent.

The possibilities of this project both for irrigation and power are dependent on the development of Tungabhadra Project. It is only when the demand increases further that it is advisable to take up the execution of the project. The figures of cost and irrigation given above are approximate and are liable to be considerably altered when a comprehensive detailed survey of the whole Kistna basin is taken in hand.

It will be seen that the State holds a very favourable position owing to the largest rivers of the Deccan, *viz.* the Godavari and the Kistna flowing through. The extent of water power that can be developed on these two rivers alone amounts to 145,000 K.W. continuous and there are possibilities of generating another 70,370 K.W. from their large tributaries, such as Tungabhadra, Manjira, Kaddam, Purna, Penganga and Manair. In all, there is the possibility of generating 215,370 K.W. or 287,160 H.P. continuous. Further, the area, that will be possible to bring under irrigation after water is utilised for the generation of power, is 26·78 lacs of acres. The total cost of all these projects amounts to Rs. 65·95 crores, and it is expected that on an average a return of 8·4 per cent will be realised.

At first sight the amount of investment required may appear enormous, but it has to be realised that this expenditure will be spread over at least half a century, if not more. The conditions are very favourable just now and it is advisable to make a start on some large Hydro-Electric Scheme. Money market to-day is exceptionally cheap and loans can be floated at a low interest. Some of these projects will pay a handsome return after meeting the interest and other liabilities. It is suggested that when the Project taken up in hand is developed fully, the surplus revenue should be set apart and on its financial backing more loans can be floated and further schemes carried out.

All these generating units will have to be connected up in one complete grid system. In any year, due to deficiency of supply, if the power is hit in a particular project, the same then can be easily supplemented from other schemes. Further, it will also be a great help in the rural electrification of the whole State.

The country lends itself admirably to large projects and future progress demands them; for a successful and rapid industrial development cheap power is an absolute necessity. Industrial progress has to be maintained side by side with educational progress, otherwise the education of the educated will end in disappointment and dissatisfaction.

"From mountains in the forests shall waters run down to lakes and thence falling into pools shall develop power and bestow new life to the country."

DISCUSSION ON SPLIT ROLLER BEARINGS AND THEIR APPLICATIONS TO INDUSTRIAL MACHINERY

Col. C. Warren-Boulton remarked that the Author gave an instance of an Axle load of 50 tons, he would like to know what effect a load of this size would have on :

(a) The "flattening" of the rollers should the load be stationery for any long period.

(b) The "Indentation", if any, on the RACE by the rollers.

A further point of interest was the "Elasticity" of the "Split" Bearing as compared with the solid, it seemed probable that a split bearing might possess more elasticity, as for example, in railroad axlebox construction, particularly when the truck or carriage was taking a curve, and there was a twisting action on the bearing. He would like to know if the Split Bearing claimed any superiority in this respect over the Solid Bearing.

Major W. D. Colin York said that he noticed that most of the Slides illustrated Split Bearings of the larger types. He would like to know if there was a limiting factor as regards the smaller diameters.

He enquired whether it was not a fact that when clamping the inner race on to a shaft of small diameter, that uneven tension of the clamping bolts would lead to distortion of the Inner Race and thus give an uneven path to the rollers.

He made this observation from his experience that with very close fits uneven clamping would easily distort a surface by ·001″ or ·002″ as was found possible by setting the tension on the Balls of a "Wickman" Gauge for fine adjustment.

Mr. P. C. Mitter asked the following two questions:

(1) If when under heavy loads the line of contact of the rollers and the races were distorted into a plane of contact, the stresses induced were much greater than could be borne by steel of ordinary quality, and therefore the steel used must be of special quality. What was the composition of this steel?

(2) The Ball Bearing is more suited for self-aligning bearings, what arrangements do you adopt for making your roller bearings self-aligning? Can this be done at a reasonable cost?

Mr. B. N. Bhattacharya enquired if any relation was established to determine the increase in friction in roller bearings with the increase of load. In case of sliding friction it varied directly as the load in accordance with the formula

F=M.R. where F= Friction. R= load and M co-efficient of friction.

In case of roller bearings the rollers were flattened down with the increase of load on the bearings above a certain specified limit and their cross-section changed from a perfect circle to what might be called an ellipse. Hence in rolling the distance a-part between the innner and the outer races continually changed depending on the difference between the major and minor axis of the flattened roller which increased with the increase of loading on the bearings. Hence there was a great deal of difference in the nature of rolling friction in case of roller bearings and Mr. Bhattacharya wanted to know if any formula was established for it.

Replying to Colonel Warton-Boulton the **Author** said that the bearings which he instanced in having an axle load of 50 tons were designed for normal stresses between the races and the rollers, the bearings being made suitable for this heavy load by having large rollers and corresponding thicker races, but there was nothing abnormal about them. When a roller bearing was loaded there was some local distortion of the roller and the race over the width of the contact area, and the surfaces in contact assumed the mean curvature of the roller and the race, but as the rollers moved along the race the surfaces came back

by elasticity to their normal form. If the roller bearing should be stationery for a long period, for instance for six months, then the rollers might cause a permanent indentation into the races, but this could be prevented if the roller bearing were rotated say once a month. The shaft was of course protected from indentation by the split hardened steel inner race, which was clamped to it, and under load both the inner race and the roller were deformed in the manner described.

The Author considered that a split roller bearing possessed more elasticity than a solid bearing. A very well-known authority on solid bearings once expressed the opinion that he wished he could find some flexible backing to the outer race in order to obtain more elasticity. This, the Author considered, was accomplished in the split roller bearing because the splitting of the outer race caused it to be less rigid on a horizontal plane and so was a definite advantage to the bearing.

In replying to Major W. D. Colin York, the Author said that with reference to the limiting factor as regards smaller diameter split roller bearings this could be provided commercially down to shaft diameters as small as 3/4″. He knew of no technical reason why they should not be made smaller, but the limiting factor was economic which applied below 1 1/4″ where the proportionate cost tended to increase. These very small bearings could be supplied where the application justified the cost. In such small bearings distortion was avoided by using clamping rings of a type which equalised the compression of the inner race on to the shaft without the need for extreme accuracy in the tightening of the clamping screws. Practical methods of equalising the tension applied just as in the case of larger sizes.

Replying to Mr. P. C. Mitter the Author said that he had described the nature of the distortion in replying to Col. Warren-Boulton, to withstand such distortion a special alloy steel such as chrome carbon steel was used, which was heat treated and hardened up to a tensile strength of 4 or 5 times that of steel of ordinary quality. In reply to Mr. Mitter's second question he did not agree that the ball bearing was more suited as a self-aligning bearing, because in a self-aligning ball bearing the balls could not run in grooves in the outer race. The outer race could be only of very slight concavity to permit the balls to swivel

and in consequence of this the stresses between the balls and the outer race were either very high, or else the whole bearing must be made large and expensive in order to keep the stresses low. In the split roller bearing which had been described, self-alignment was not taken up in the bearing itself, but the bearing was mounted in a housing which swivels in a spherical seating, and thus the bearing becomes self-aligning with very low stresses in the spherical seating and this was done at quite a reasonable cost which was very comparable with that of the solid type of ball and roller bearing.

Replying to Mr. B. N. Bhattacharya the Author said that the friction of a roller bearing consisted of two parts. (1) That part which was independent of the load, namely cage friction, friction due to lubricant etc. and (2) that part which was dependent on the load, namely the work done in deflecting the rollers and the races. The Author had developed a formula for the second part of the friction due to the work done in deflecting the rollers and the races, and had shown that this friction was proportionate to the square root of the load on the bearing, but he had not yet published this formula. Taking the second part of the friction in conjunction with the first part of the friction, which remained constant, it would be seen that in a roller bearing the friction increased only very slowly as the load increased and so the roller bearing showed a considerable advantage over the plain oil lubricated bearing in which the sliding friction, as Mr. Bhattacharya said, increased in direct proportion to the increase of load. Mr. Bhattacharya was not quite correct in assuming that in a roller bearing under load the roller changed from a perfect circle to an ellipse. As explained in the earlier part of this reply the contact surface between the roller and the race, which might be about 2/100" wide, slightly distorted under load, the form of the distortion being such that the curvature became the mean curvature of the roller and the race.

ACTIVITIES OF LOCAL CENTRES.

A General Meeting of the Institution of Engineers **(India),** Bombay Centre, was held on Friday, 15th **September** 1939 at 6-15 p.m. (S. T.) in the Institution Room, **when** Mr. S. K. Talageri, L.C.E., gave a lecture on "Fundamentals of Law, with Special Reference to the Proposed Amendments to the Municipal Building Regulation."

In the absence of the Chairman, Mr. N. V. Modak was duly proposed to the Chair.

28 members and 12 guests were present.

Mr. Modak welcomed Mr. Rahimtullah Chinoy, a member of the Bombay Corporation and other guests and said that he wanted some constructive criticisms from the members which may be of use to him when presenting the amendments to the Bombay Corporation for approval. **Mr. N. V. Modak.**

Mr. Talageri said that his object was not to critically examine all the Revised Bye-Laws but to explain the implications of some of them with reference to the Principles of Law behind them. All law set forth restrictions on the individuals in the interest of the community and the three objects behind the restrictions imposed by the Building Bye-Laws were Sanitation, Stability and Safety from Fire. The three Fundamentals of Law were (1) no encroachment on right of others in exercise of ones own, (2) co-operation in the interest of common good, *e.g.*, Taxation, (3) no one shall obstruct an act intended for the benefit of the community, *e.g.*, Land acquisition. **Mr S. K. Talageri.**

The speaker was of opinion that beyond the three requirements of Sanitation, Stability and Safety from Fire—the Bye-Laws should not touch other matters which should be left to adjust themselves to economic forces.

He then explained that the Act overrides the Bye-Laws and that anything mentioned in the latter could not bind the former. He was therefore of opinion that some definitions will have to be incorporated in the Act, *e.g.*, 'construction work of a building' etc.

He referred to Bye-Laws 259 A (3) and 353 A and expressed the opinion that it was unfair on the part of the Commissioner to interfere with the contractual rights of the Licensed Surveyor as between him and his client by demanding from him the completion certificate under compulsion without making any provision for the collection of his dues from his clients on the lines of the Taxing system in Solicitors' Profession.

He then referred to page 133 and said that control of elevations would be unfair to the Building owners. Referring to page 134 (3a) he referred to the compulsion on the provision of garages and servant quarters for all four room tenements and thought that this seemed to be an unwarrantable presumption that every tenant living in a four room block keeps a car and a servant. These in his opinion were not essential requirements and should be left to economic adjustments.

He similarly referred to page 99 Section 302 to the compulsory provision for living and sanitary accommodation for chauffeurs in the development of buildings.

He then referred to page 28 Section 348 (bb) and thought that even ordinary repairs could be stopped by the Commissioner. His experience was that 'written permission of the Commissioner' was a dangerous terminology as the Commissioner could impose any conditions without assigning reasons.

He thought that proposed roads and their lines had no status and could be changed at any time to the great disadvantage of those who are required to submit to certain restrictions on the presumption of the road proposed.

He then discussed the penal provisions regarding fine and thought that they were, many times, unworkable without the co-operation of the Magistracy. He thought the Corporation was wrong in not co-operating with the Government in the matter of appointment of Magistrates.

The meeting was then adjourned to **Wednesday, 11th** October, 1939.

A General Meeting of the Institution of Engineers **(India)**, Bombay Centre, was held on 11th October **1939 at 6-15 p.m.** (S. T.) in the Institution Room, when Mr. S. K. **Talageri** continued his lecture on "Fundamentals of **Law, with** Special Reference to the Proposed Amendments **to the** Municipal Building Regulations."

Mr. T. R. S. Kynnersley, Chairman, occupied the **Chair.**

23 members and 10 guests were present.

Mr. Talageri continuing his lecture referred to the "Written permission of the Municipal Commissioner" referred to in the proposed Building regulations and said that legally the Commissioner could impose any conditions, without assigning reasons, with such a written permission and could charge fees as well. **Mr. S. K. Talageri.**

He then showed the contradiction between Sections 345 and 354, the former presumed the permission of the Commissioner by implication if the Commissioner did not dispose of the matter within 30 days and the latter made such permission obligatory.

He then referred to the wording "If the Commissioner is satisfied" in Section 354 and said that powers of interpretation which should ordinarily vest in a court of law were being taken upon himself by the Commissioner. Referring to Section 354 AA (page 159) the lecturer approved of the provisions so far as dangerous buildings were concerned, but found that the proposed amendments were to apply to buildings which exist in contravention of the Bye-Laws. This was unfair as there were buildings in Bombay which exist since before the Bye-Laws came into force.

He then referred to Section 348 (1) bb (page 129) and suggested a definition of 'New Buildings' as 'A building constructed on virgin soil as well as buildings on previously built upon soils'. Although the Section referred to new buildings, the term construction of work refers to repairs also.' Heading of the Section also will have to be amended.

The lecturer thought that the road lines determined by the Commissioner had no status and was liable to be changed by the Corporation and that it was unfair to put restrictions on the owner of a building on the assumption of an uncertain road line.

Referring to Section 337 A, Mr. Talageri was of opinion that the Section went beyond the fundamentals of law and that the limit of 50 years age of the building was arbitrary and impractical as it was difficult to determine the age of a building, because a building shown on Loton Sheets as 60 years old may have been reconstructed only 40 years back. In his opinion the Section was unnecessary and that if it was applied 60 per cent of the buildings in Bombay would either have to go or would have to stand without repairs.

Referring to the possible plea of slum clearance for putting such drastic provisions in the Bye-Laws Mr. Talageri said that the Municipal Commissioner had ample powers under the existing Bye-Laws to remove the slums but the staff was insufficient to do that work. The Corporation had turned down the proposal that every building should be got inspected periodically by a Licensed Surveyor saying that the Municipal staff itself should be vigilant, but did not provide the necessary staff.

Again Section 378 was wide enough as it empowered the Commissioner to prohibit further use of a place if it should appear to him, for any reasons, that the said place was unfit for human habitation. He thought that 50 per cent of the buildings in Bombay would be reconstructed without the asking if these powers were used by the Commissioner.

Referring to Section 348 (A) 3b (page 136), regarding visibility, he thought it inequitable to expect a builder to leave some space of his land unbuilt upon for visibility or further widening, without getting compensation for the encroachment upon his rights. He was afraid that such a Section would give rise to litigation against the Municipality under the Specific Relief Act. It was his experience that the reason why there had been no litigation in the past with regard to Section 293 also was that the Municipality compromised the cases whenever there was a possibility of litigation.

He similarly referred to the building lines under Section 297 (pages 85, 86) and thought it unfair to deprive the owner of a building of his due compensation by requiring him to leave some of his land unbuilt upon for future widening of road.

He concluded his lecture by a reference to similar inequitable provisions of the new proposed Bye-Laws regarding house gullies.

The Chairman, Mr. Kynnersley, remarked that instead of waiting for a hundred years to get house gullies as wide as 10' we might as well find a mechanical means of cleaning them. He proposed a vote of thanks to the lecturer which was carried unanimously. The Chairman.

The meeting terminated with a vote of thanks to the Chair.

A General Meeting of the Institution of Engineers (India), Bombay Centre, was held on Wednesday, 27th September, 1939 at 6-15 p.m. (S. T.) in the Institution Room when Rao Saheb N. S. Joshi, M.I.E., gave a lecture on "Phonetic System of Telegraphy", invented by himself.

Mr. T. R. S. Kynnersley, Chairman, occupied the Chair.

34 members and 3 guests were present.

Rao Saheb Joshi first of all explained how it was essential to transmit and receive messages in the language in which they were given. He said that the present method of reproducing messages in oriental languages by 'spelling' them into English was objectionable as the English alphabet was not phonetic and mere spelling could not convey the pronunciation and consequently the sense and the meaning of the original word was lost. He gave illustration of the word 'Nala' which could have widely different meanings according to the way it was pronounced. Rao Saheb N. S. Joshi

He said that some people thought that the method of translating the original message in English was very satisfactory and illustrated how every language had words and ideas which were altogether foreign to the English language and hence incapable of translation.

[illegible] explained how the 'Devnagari' alphabet was more [illegible] phonetic, *i.e.*, they were grouped according to the size [illegible] mouth orifice and the position of the tongue. He then [illegible] how the 'Long' and the 'Short' in the telegraphic [illegible] could be combined at one-two or three or four at a time [illegible] the desired number of signals. He had reduced the [illegible] number of signals required for the 'Devnagari' by distinguishing 'KA' and 'KHA' by a 'Long' for the latter.

Rao Saheb had trained his daughter in his system of 'Phonetic Telegraphy' and actually demonstrated how messages in any language including Urdu, Arabic, etc., could be transmitted and received without mutilation.

Mr. R. K. Nariman made some useful suggestions.

The Chairman Mr. Kynnersley, expressed that it was a matter of pride for the Institution that one of its own members should get the credit of an invention so useful to India. He said that it was gratifying to note that the Governments of U.P. and Bombay have requested Rao Saheb Joshi to train two of their signallers in his system. In conclusion he expressed his thanks and appreciation on behalf of the Institution to Miss Joshi for the interest and the trouble she had taken in coming to Bombay and demonstrating the system.

The Meeting terminated with a vote of thanks to the Chair.